Materials
in Design Engineering

FORMERLY MATERIALS & METHODS

SELECTION & USE OF METALS, NONMETALLICS, FORMS, FINISHES

July, 1957

Magnesium and Its Alloys—Manual No. 139

Special Report: The Fluoro-Elastomers

Zinc Paints Protect Steel

Fatigue Data on Reinforced Plastics

Cast Epoxy Insulation

Where to Use Knitted Metal Parts

Complete Contents—page 1

PRICE ONE DOLLAR

For more information, turn to Reader Service card, circle No. 390

WILLIAM P. WINSOR
Publisher

H. R. CLAUSER
Editor

JOHN B. CAMPBELL
Managing Editor
JOHN L. EVERHART
Technical Editor
ROBERT J. FABIAN
Associate Editor
JACK C. MERRIAM
Associate Editor
MALCOLM W. RILEY
Associate Editor
WALTER LUBARS
Assistant Editor
JOHN A. MOCK
Assistant Editor
HARRY KOKIS
Editorial Production Asst.
GIL MILLER
Art Director

M. RANDOLPH LONG
Advertising Sales Manager
JOHN Y. CUNNINGHAM
Research & Promotion Manager
MAUD CORE
Asst. Research Manager
JOHN N. CARLIN
Circulation Director
JOHN A. KOVCHOK
Production Manager
GLORIA de LATTAIGNANT
Advertising Production Manager
E. M. WOLFE
Manager, Reader Service

Published monthly by
REINHOLD PUBLISHING CORP.
430 Park Avenue
New York 22, N. Y.

RALPH REINHOLD
Chairman of the Board
PHILIP H. HUBBARD
President & Treasurer
K. A. STARKE
Asst. Treasurer
F. P. PETERS
Vice President & Secretary
A. E. FOUNTAIN
Vice President
H. BURTON LOWE
Vice President
MERALD LUE
Vice President
D. BRAD WILKIN
Vice President
WILLIAM P. WINSOR
Vice President

This periodical is indexed regularly in the Engineering Index and the Industrial Arts Index

Materials in Design Engineering

formerly Materials & Methods

Selection & use of metals, nonmetallics, forms, finishes

JULY 1957

VOL. 46, NO. 1

PRICE $1.00 PER COPY. PAYABLE IN ADVANCE, ONE YEAR, $3.00; TWO YEARS, $5.00 IN U. S., POSSESSIONS AND CANADA. IN ALL LATIN AMERICAN COUNTRIES: ONE YEAR, $10.00; TWO YEARS, $16.00. ALL OTHER COUNTRIES: ONE YEAR, $15.00; TWO YEARS, $25.00 (REMIT BY NEW YORK DRAFT). COPYRIGHT, 1957, BY REINHOLD PUBLISHING CORPORATION, NEW YORK, N. Y. PRINTED BY PUBLISHERS PRINTING CO. SECOND CLASS MAIL PRIVILEGE AUTHORIZED AT NEW YORK, N. Y. ADDITIONAL ENTRY AT BROOKLYN, N. Y.

What's new IN MATERIALS

...AT A GLANCE

INORGANIC ELASTOMER SYSTEMS, still in the basic research stage, may be the high temperature rubbers of tomorrow. Among the most promising are the boron-phosphorus, nitrogen-phosphorus and chelate polymer systems. (See article on page 90 for further details).

AN IMPROVED ULTRA HIGH STRENGTH STEEL is said to have greater strength at elevated temperatures than any other ultra high strength steel yet produced. According to the producer, the steel can be easily formed, welded and machined. It is recommended for aircraft landing gears, engine mounts and fasteners.

TWO NEW SILICONE RUBBERS have been developed for use at temperatures of 600 F. Both rubbers are designed primarily for cloth coating and are said to have good bond strength and low compression set. They are currently available in commercial quantities for such applications as aircraft hose and ductwork.

RAYON-REINFORCED PAPER is now commercially available. The rayon reinforcement is said to give strength to the paper in all directions and to make it puncture resistant. It is presently being used in mail sacks, shrouds, tarpaulins, temporary barriers, tents and awnings.

RADIATION RESISTANT CERAMIC PELLETS are being used as nuclear fuel elements. Unlike metallic fuel elements, ceramic elements do not grow and become distorted under intense irradiation. Other advantages of ceramic fuel elements are their ability to withstand high temperatures and their excellent resistance to corrosion in water.

A BETTER HIGH TEMPERATURE COATING based on a new silicone resin is said to provide much greater gloss retention after long exposure than previously possible. Cured films of the resin are claimed to be nonyellowing and to show excellent adhesion, flexibility, and resistance to moisture and many common chemicals. The resin is designed primarily for use in white and light-colored finishes.

REINFORCED PLASTICS are finding wide use in rockets and missiles. For short, one-shot operations, the temperature tolerance of reinforced plastics parts is said to often exceed that of metallic counterparts. The advantages listed for use of reinforced plastics in rockets include: ease of fabrication into complex parts; use of noncritical materials; and good resistance to solvents and

fuels. Some typical reinforced plastics parts used in rockets are liners, baffles, cones and deflectors

ALUMINUM COATINGS are being successfully applied to magnesium by a new vapor plating technique. Recent work with high purity aluminum shows that it is very promising as a protective coating for magnesium parts operating in a corrosive atmosphere. No satisfactory method existed for applying the coating until the new vapor plating technique was developed.

SINTERED TITANIUM POWDERS are said to have the same excellent high temperature strength and stability of sintered aluminum powders, with the added advantage of having higher melting points. (The relatively low melting point of SAP-type materials limits their use in many high temperature applications.) The new titanium powders are not commercially available at present.

SILICONE DYES FOR COLORING GLASS CLOTH have recently been developed. With these dyes it is possible to give dark and permanent colors to glass cloth. Formerly, glass cloth had to be coated before dyeing and the color, at best, was semipermanent and limited to pastel shades.

A NEW ALUMINUM ALLOY FOR BRIGHT ANODIZING has been developed in Britain. The aluminum alloy containing 1-1/3% magnesium, is said to combine good brightening characteristics with high strength. The alloy is recommended for use in anodizing decorative wares, home appliances and automotive trim.

NEW HIGH STRENGTH CERAMICS can be formed by any of the conventional glass-forming techniques. Crystallized glass in nature, the materials have an excellent strength-weight ratio, are extremely hard, and have excellent thermal shock resistance and dielectric properties. They retain most mechanical properties up to 1300 F. (See page 142 for more details.)

INEXPENSIVE PHENOLIC FOAMS are possible with a new foam-in-place technique. According to the producer, it is possible to produce a phenolic foam of controlled density by carefully mixing measured amounts of phenolic resin and catalyst together. The new technique is said to provide rapid conversion of liquid resin into infusible foam.

LARGE SYNTHETIC SAPPHIRES are now commercially available. The sapphires are said to be competitive in price with sintered aluminas and quartz; a disk 3 in. in dia and 1/8 in. thick costs about $135. Synthetic sapphires, having extreme hardness and good resistance to acids and alkalies, are currently used as radiation pipes, ball points for pens, and phonograph needles.

Turn to page 141 for more "What's New in Materials."

MATERIALS BRIEFS

Lettuce Not Wilt
An electric aluminum sheet crisping tray keeps foods crisp in wet weather. The tray, 10 x 14 in., uses 18 w of electricity.

Nickel in a Sweat
Corrosion resistant, small diameter nickel tubing is used to make hinges on the nose piece of eye glasses. Plain carbon steels, formerly used for this application, are attacked by perspiration.

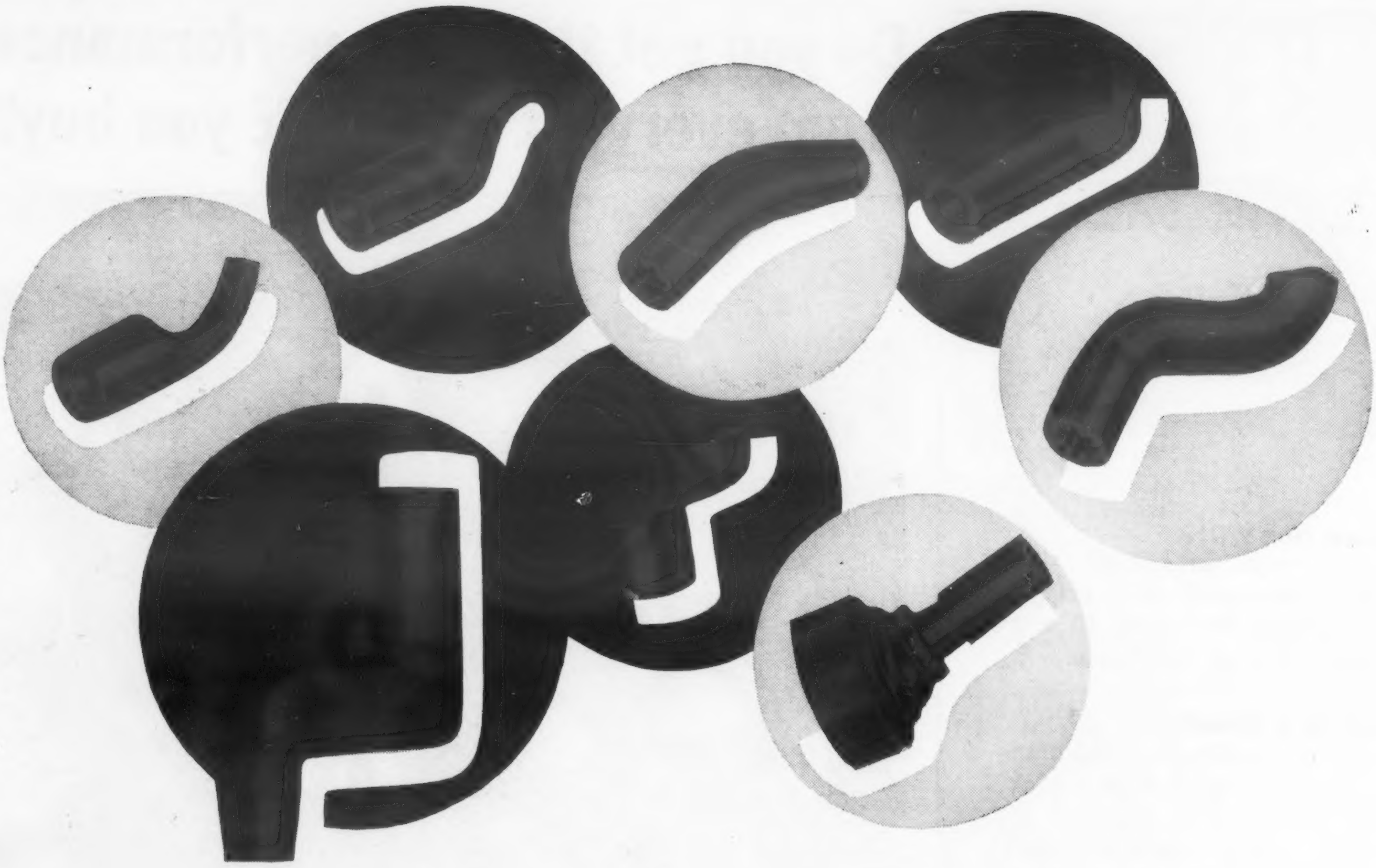
A New Wrinkle
A new device measures the number and size of wrinkles in any fabric. A pointer "feels" a fabric and deflects a light beam, giving a direct voltmeter reading of the number of wrinkles in the fabric.

Hair Raising Climb
A lightweight plastics ladder resists the shock of 120,000 v of electricity. Made of glass fiber-reinforced polyester resin molded over a balsa wood core, the ladder is ideal for use in power and electrical work.

Rain, Rain, Go Away
A "whirling arm" studies the effects of rain on materials traveling at high speeds. Chromium and nickel-containing alloys show the greatest resistance to rain erosion. The average life of most plastics and synthetic rubber coatings is approximately 30 sec at 500 mph in 1 in. per hr rainfall.

Big Mouth
A power shovel as high as a 16-story building contains 117 tons of alloy steel castings. One scoop of its bucket can fill two railroad hopper cars with coal.

For more information, turn to Reader Service card, circle No. 468



9 times out of 10 . . .

Standard Mallory Tips Fit Your Special Resistance Welding Jobs

Before you order a "special" welding electrode, ask your Mallory welding distributor to check your requirements against hundreds of *standard* Mallory tips. Chances are he'll be able to find exactly the shape and size you need. And he can deliver it promptly—at *standard price!*

The Mallory standard electrode line is the widest anywhere. It includes straight electrodes with many nose shapes, tapers and lengths . . . scores of models of single and double bent electrodes, cold forged for extra hardness and life . . . cast and forged offset types in unusual shapes. Designs include exclusive Mallory features for extra service . . . such as the patented Mallory fluted cooling hole, and bent-in-place cooling tubes. Our electrodes are made with alloys developed during more than thirty years of pioneering in resistance welding materials.

And for that rare job that really needs special treatment, call on Mallory to design and make the custom-tailored electrodes that will give peak economy on your machines.

For prompt service and valuable help, see your local Mallory Welding Distributor. Write for the name of the one serving your area.

OVER 30 YEARS OF RESISTANCE WELDING LEADERSHIP

In Canada, made and sold by Johnson Matthey and Mallory, Ltd., 110 Industry Street, Toronto 15, Ontario

Serving Industry with These Products:

Electromechanical — Resistors • Switches • Tuning Devices • Vibrators
Electrochemical — Capacitors • Mercury and Zinc-Carbon Batteries
Metallurgical — Contacts • Special Metals • Welding Materials

P. R. MALLORY & CO. Inc.

MALLORY

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

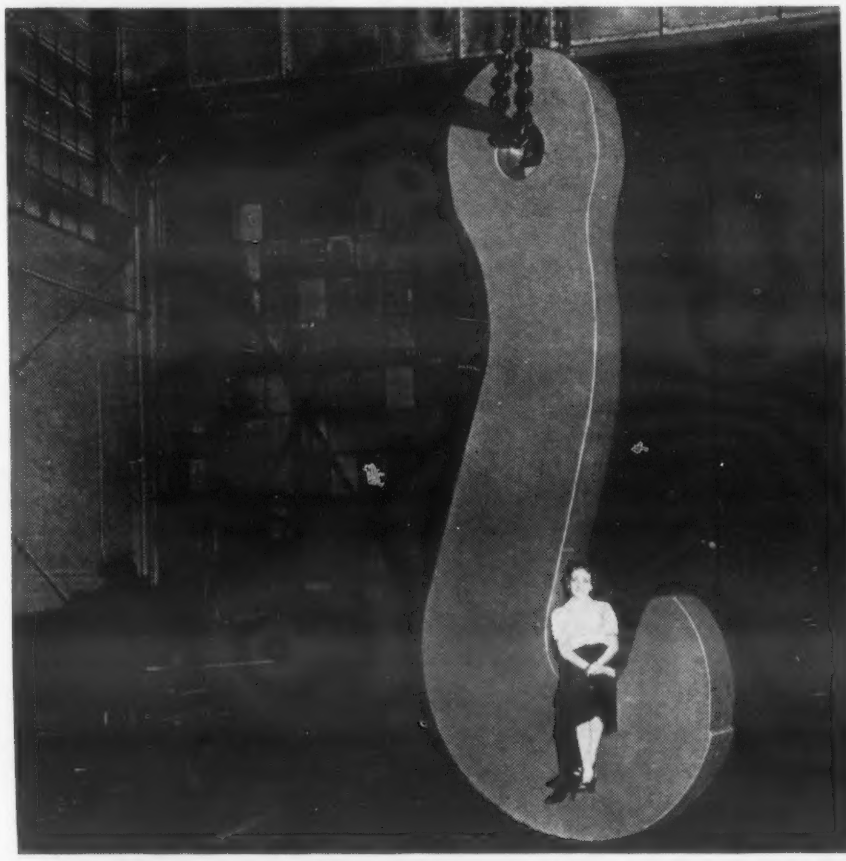
For information on titanium developments, contact Mallory-Sharon Titanium Corp., Niles, Ohio

For more information, turn to Reader Service card, circle No. 388

MATERIALS AT WORK

New and interesting applications of engineering materials

Plate sections *are riveted together to form . . .*



. . . 250-ton hook, *which will be used to lift a much heavier and less attractive load.*

Hooks for ladle crane made of laminated steel plate

This 250-ton hook is one of two used on what is claimed to be the world's largest ladle crane. Designed and manufactured by Morgan Engineering Co., the 500-ton-capacity crane weighs 1,841,000 lb; is driven by 11 electric motors (1685 hp); is reeved with 1⅜ miles of steel wire rope or cable; and handles a ladle that has a 17 ft top dia, and is 17 ft, 3½ in. high.

The ladle hooks are 17 ft, 5 in. long, 7 ft, 3 in. wide and 12½ in. thick. They are composed of four ⅞-in. and nine 1-in. thick laminated steel plates held together with 1¼-in. dia rivets. The two hooks have a combined weight of 68,000 lb.

Outstanding advantage of the new crane, which will be used in steel mills, is that it reduces from three to one the trips necessary from furnace to mold to complete a given pour.

MATERIALS AT WORK

Aluminum emblems cold forged in one piece

One-piece construction makes these aluminum coined letters, emblems and script plates easy to install. Manufactured by Etched Products Corp., the lug is cold forged from the plate, making the lug and plate one integral unit (see cross section). As a result, the lugs can be easily turned or used with any standard fasteners and they may be any size or shape. They can be anodized in any color.

Eastman Chemical Products, Inc.

Uranium and music too!

A tough, impact resistant butyrate case is used to house the latest appliance developed as a result of the atomic age. The device, called the Cae Lodestar and manufactured by Canadian Aviation Electronics Ltd., is a combination Geiger counter and portable radio.

Operated like a conventional radio, the device will either flash a light or produce a clicking noise in the presence of uranium or other radioactive material. In the meantime, there's music.

Cellulose acetate butyrate was selected because of of its light weight (the complete unit weighs less than 5 lb), durability and ease of molding.

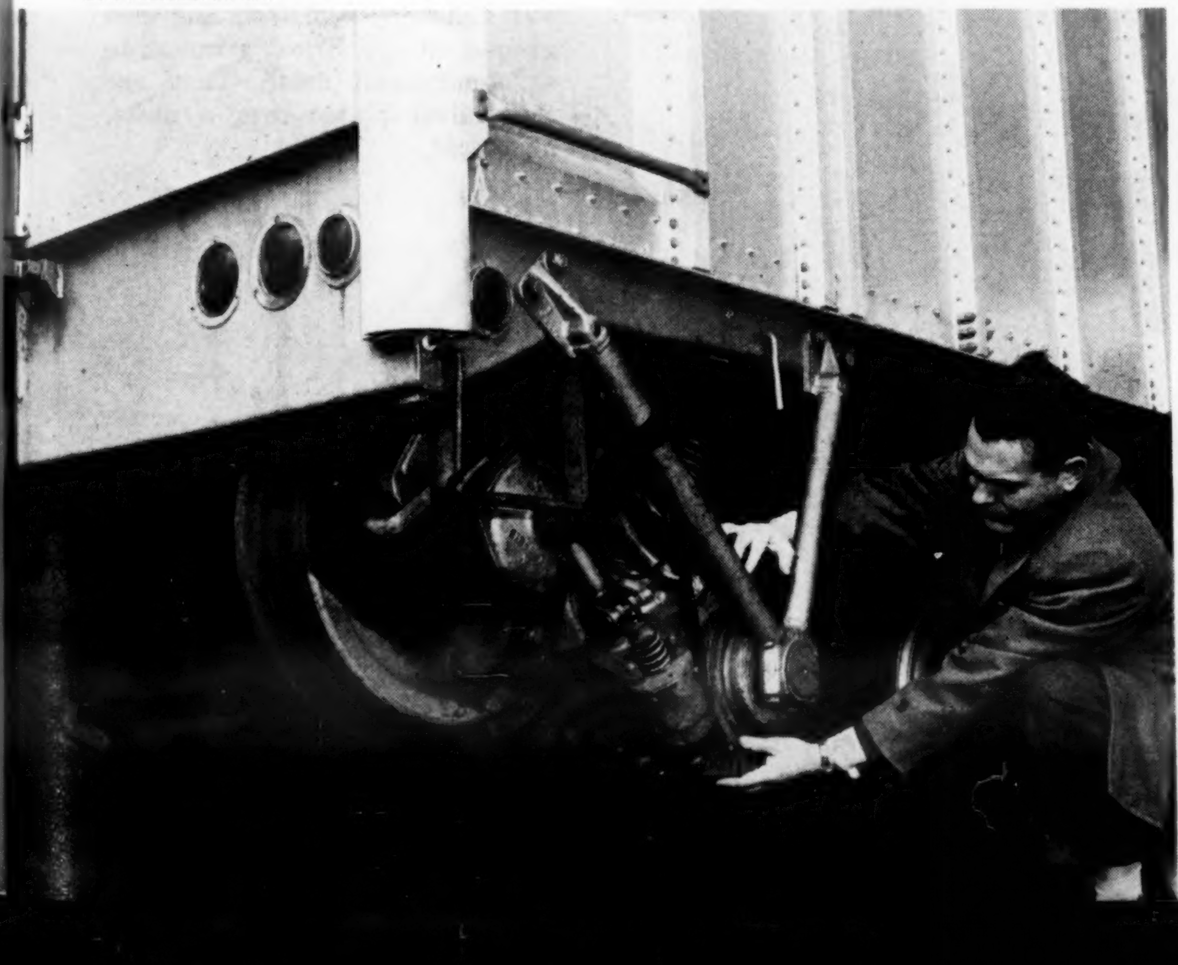
Nylon aerosol containers

These aerosol containers blow molded of Du Pont's new Zytel 42 nylon resin (see M&M, Feb '57, p 154) have so effectively combined strength, beauty and utility that they are being used for cosmetics, pharmaceuticals and other personal items.

In addition to the fact that blow molding makes possible a wide variety of shapes, this type of fabrication produces an extremely durable one-piece bottle. According to Du Pont, the material maintains form stability at high temperatures, has extremely high impact strength, is light in weight, and is resistant to most chemicals and solvents. The aerosol containers are available in many colors.

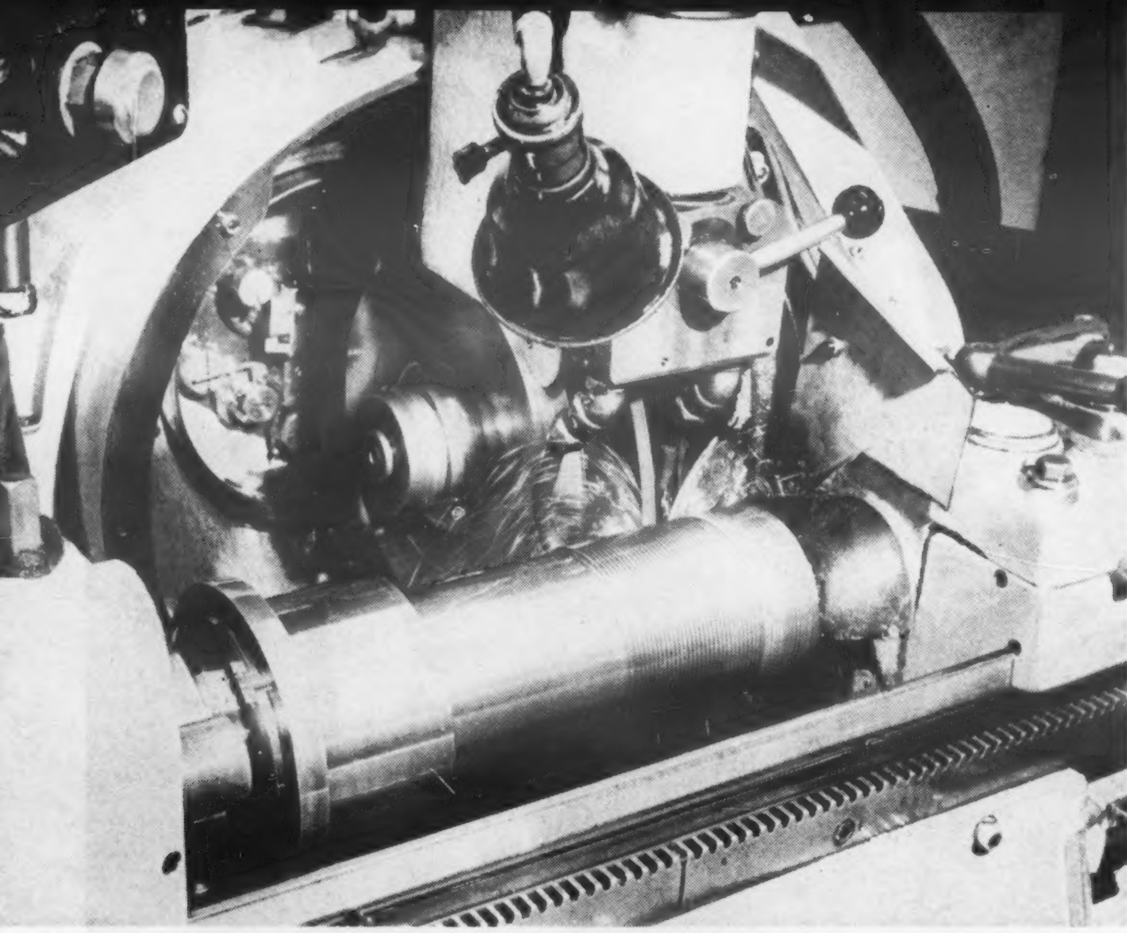
Rubber converts boxcar into semi-trailer

B. F. Goodrich Co.



About 48 lb of rubber and an ingenious design are making possible the conversion of Chesapeake and Ohio railway freight cars into highway bound semi-trailers, and vice versa.

The vehicle, called Railvan, is equipped with both rail wheels and highway wheels. The arms supporting both sets of wheels are attached to the outer casing of a special spring, which consists of a rubber tube bonded to an inner, stationary metal tube and a movable outer metal sleeve. Deflection of the rubber provides the necessary elasticity, and a motor-driven gear train transfers the wheels from highway position to rail position or vice versa in about 30 sec.



Threads *for steel screws are cut on centerless grinders and . . .*

. . . **completed screw** *is wrapped with paper liner for shipment.*

MATERIALS AT WORK

80-lb steel screws are precision cut

Hexagonal socket-head cap screws measuring 4½ in. in dia and weighing 80 lb each are machined from high-carbon chromium-molybdenum steel for use in the supersonic nozzle assembly of the largest propulsion wind tunnel in the United States, presently being constructed for the Air Force.

The king-size screws, fabricated by Cleveland Cap Screw Co., are made in two lengths: 10¾ and 9½ in. Despite the size of the screws, the threads are cut to the finest commercial tolerance (Class 3).

The screws are fabricated by first machining heads and shanks. After threads are formed, the screws are heat treated to a Rockwell C hardness of 38-42 and then ground on cylindrical grinders to a 32-microinch finish. They are then silver plated over a nickel undercoat.

TA

line
req
and
nee

TAKE A CLOSE LOOK AT THE FULL LINE OF RCI

PLYOPHEN

PHENOLIC RESINS

● When your production calls for phenolics, be sure you call Reichhold—where a full line of RCI PLYOPHENS is available for your bonding, laminating, impregnating or casting requirements ● RCI offers you more than 40 individual PLYOPHENS—including both liquids and powders ● For full information on how RCI PLYOPHENS can best serve your individual needs, clip and mail the check list below. Technical information will be sent to you promptly.

My Name is ____________________

I am ____________________
(TITLE)

of the company indicated on this letterhead.

Please send me full technical information on the use of RCI PLYOPHEN Phenolic Resins for:

- ☐ Brake Linings
- ☐ Resinoid Grinding Wheels
- ☐ Wood Waste Molding
- ☐ Decorative Laminate Core Stock
- ☐ Casting
- ☐ Hot Punching Stock
- ☐ Cold Punching Stock
- ☐ Gear Stock
- ☐ Rolled Tubing
- ☐ Insulation Bonding
- ☐ Plastic Faced Plywood
- ☐ Shell Molds
- ☐ Shell Cores
- ☐ Surface Coating

REICHHOLD

Synthetic Resins • Chemical Colors • Industrial Adhesives
Phenol • Formaldehyde • Glycerine • Phthalic Anhydride
Maleic Anhydride • Sebacic Acid • Sodium Sulfite • Pentaerythritol
Pentachlorophenol • Sulfuric Acid

REICHHOLD CHEMICALS, INC.,
RCI BUILDING, WHITE PLAINS, N.Y.

Creative Chemistry ... Your Partner in Progress

RCI

For more information, turn to Reader Service card, circle No. 492

We lost our bearings

To the Editor:

My article "Aluminum-Tin Bearings," published in the June issue of MATERIALS & METHODS, was printed with an error in Fig 3, p 113. The curves at the top which are now labelled "Lubral" should be labelled "T.R.I." The curves in the middle should be labelled "Lubral" and the lower curves "Titanium-containing alloy."

As Fig 3 now stands it makes high tin bearings appear to give higher wear than the other types.

E. C. ELLWOOD
Chief Metallurgist
Tin Research Institute
Middlesex, England

We regret that the labelling of curves in the original manuscript was misinterpreted and advise our readers to take note of the correction.

The tin market . . .

To the Editor:

The prices and supply outlook written by Herman B. Director for your May issue, page 284, contains inaccuracies of such seriousness as to warrant correction. We refer specifically to the paragraph on tin.

Initially, there is no "world tin cartel." Presently six countries produce the bulk of the world's tin — Malaya, Indonesia, Bolivia, Belgian Congo, Thailand and Nigeria. Of these, Malaya, alone provides over two-thirds of America's needs. And in Malaya tin ore is mined by companies capitalized from all over the world.

Secondly, it was on March 23 that the International Tin Council, not the Tin Producers Assn., agreed *unanimously* to alter the authority of its Buffer Stock Manager as to buying and selling.

Thirdly, this same International Tin Council consists of the *governments* of Australia, Belgian Congo, Belgium, Bolivia, Canada, Denmark, France, India, Indonesia, Italy, Malaya, Netherlands, Nigeria, Spain, Thailand, Turkey and the United Kingdom. These include consumers as well as producers. The Buffer Stock Manager is an employee of all these *governments*, producers and consumers of tin alike, and not of "the producers buying agency."

Fourthly, the new levels of authority for the Manager range as follows (prices in U. S. dollars):

	Old	New
Must buy	.80	.91¼
May buy	.90	.97½
Neutral	.90–1.00	.97½–1.03¾
May sell	1.00	1.03¾–1.10
Must sell	1.10	1.10

As a result, the Manager on recent markets has had the *opportunity* of buying tin. At the old 80-90¢ level this was not possible, for the open market, operating

For more information, turn to Reader Service card, circle No. 515

under the law of demand and supply, had established prices in excess of that. At the more realistic new levels, the Manager can buy tin, to be sold when prices should rise above \$1.03¾. In fact then, this International Tin Council is protecting the American consumer by limiting the ceiling price of tin and reducing the likelihood of sharp price rises.

Lastly, it must be remembered that tin modifies the prices of packaging materials to a lesser degree than other raw materials.

R. D. COURSEN
Deputy Director
Malayan Tin Bureau
Washington, D. C.

. . . and a rebuttal

To the Editor:

Our choice of the words "world tin cartel" is perhaps unfortunate. However, it is generally conceded that the principal task facing the "Buffer Stock Scheme" is to regulate the price of tin. The fact that the Tin Council contains governments as well as producers and some consumers of tin does not alter the basic price regulating purpose of this voluntary combination.

The United States, which is by far the largest consumer of tin in the world, is not a member of the Tin Council, nor does the United States participate in any of the activities of the Buffer Stock Scheme, although U. S. consumers are most directly affected by the activities of both the Tin Council and its agent, the Buffer Stock Manager. We doubt that the consumer voice is prominently heard in the Tin Council even though the United Kingdom, which possesses over 40% of the votes, is a consumer. A. Strauss and Co., Ltd., which is recognized as the world's leading authority in the tin market, states with respect to the United Kingdom in its Jan '57 bulletin that "in view of this country's interest in the welfare of Malaya it is probable that she will approach the problem from a producer's rather than a consumer's angle."

Actions taken by the Buffer Stock Manager thus far seem to indicate that the principal concern of this Scheme is to forestall a severe drop in price. The Tin Council recently agreed to raise the "floor level" at which the Buffer Stock Manager may enter the market to purchase tin. Published reports from the United Kingdom indicate that the current price of tin is being supported by purchases for the Buffer Stock inventory.

It remains to be seen whether the Buffer Stock Manager will act to sell tin in the event prices begin to move upward. Action on the part of producers to stop an increase in the price of tin would indeed be an unusual and courageous step.

Personally, we would prefer to see the price of tin regulated by supply and demand conditions rather than by a combination of governments, producers, consumers or anybody else.

HERMAN B. DIRECTOR
Consultant
Washington, D. C.

ONE POINT OF VIEW

Our job: helping you select materials

With this month's issue our name officially becomes MATERIALS IN DESIGN ENGINEERING. Last month (p 101) we explained why we decided to drop the name "Materials & Methods" in favor of our new title. This month we want to explain what MATERIALS IN DESIGN ENGINEERING means, and show how it fits our long established editorial objectives.

What 'Materials' means

The research conducted to find the most suitable name for the magazine revealed that the meaning of the word materials depends a lot on who is doing the defining. It was found that the average man or woman on the street thinks of materials as various types of fabrics. To others who have a casual or indirect acquaintance or connection with industrial activities, the word materials often brings to mind chemicals, concrete and other building or construction materials.

But none of these things is what we mean by the word materials. The materials our title refers to are those which engineers and designers work with, select and specify for manufactured products. Technical men frequently refer to them as engineering materials. They include the thousands of ferrous and nonferrous metals and alloys, as well as the thousands of nonmetallics such as plastics, rubber, and ceramics —just to mention a few.

But our use of the word materials (and engineering materials) goes beyond the basic materials themselves. The designer or engineer seldom selects a material without also specifying the form in which it is to be used or produced. For example, he doesn't select or design with a plastics resin, but rather designs in terms of a plastics molding, extrusion or some other form. It is because of this close interconnection between basic materials and their forms that we include forms — castings, forgings, moldings and all the others— in our definition of materials.

In our definition of materials we also include finishes and coatings. This is a natural and logical addition, since the engineer and designer who selects a material and its form must also specify its surface. Whether the surface is integral with the base material, as in the case of conversion coatings, or applied, such as paints and electroplates, the surface actually is or functions as an engineering material with its own set of characteristics.

What 'Design Engineering' means

In recent years design engineering has come to be well recognized as the broad field of technology encompassing all of the great many activities that go into the planning, designing and engineering of fabricated products. One of the most important parts of the design engineering job is searching for and finally selecting the best materials for products. This selection task begins early in the initial design stages. It continues through all of the product planning, engineering and testing phases. And the task does not end until all the problems associated with processing or fabricating the materials into the product are solved.

Our magazine is devoted exclusively to this materials selection function, and over the years we have come to be recognized as the materials magazine of the design engineering field. It is therefore appropriate that our new name should be MATERIALS IN DESIGN ENGINEERING.

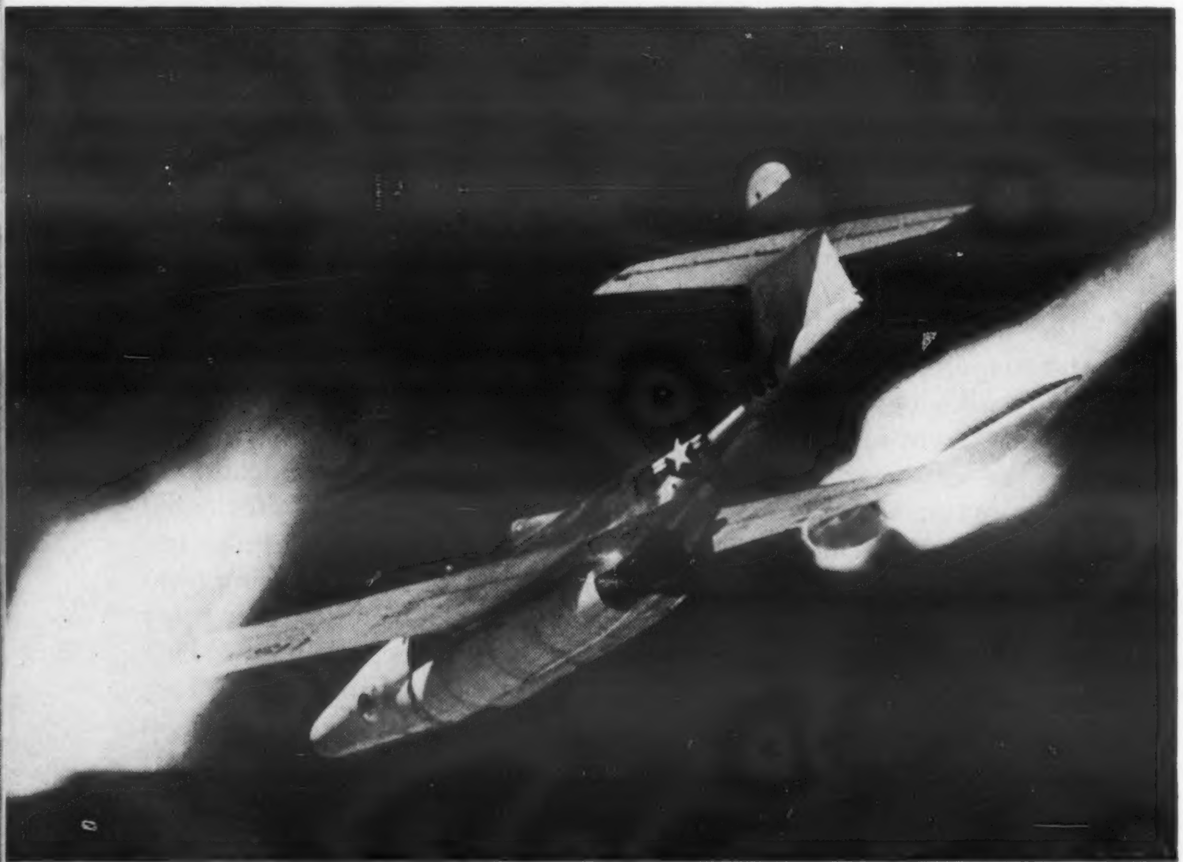
A SPECIAL REPORT

The Fluoro-Elastomers:

Latest Weapon Against Heat and Fluids

This exclusive report compares and summarizes data just released on the five fluorinated elastomers, the newest family of rubbers developed to withstand corrosive fluids and extremes of temperature.

by Malcolm W. Riley, *Associate Editor, Materials in Design Engineering*



Northrop Aircraft Inc.

***Critical demands** for chemical and high temperature stability in today's aircraft have stimulated much of the work on fluorinated elastomers.*

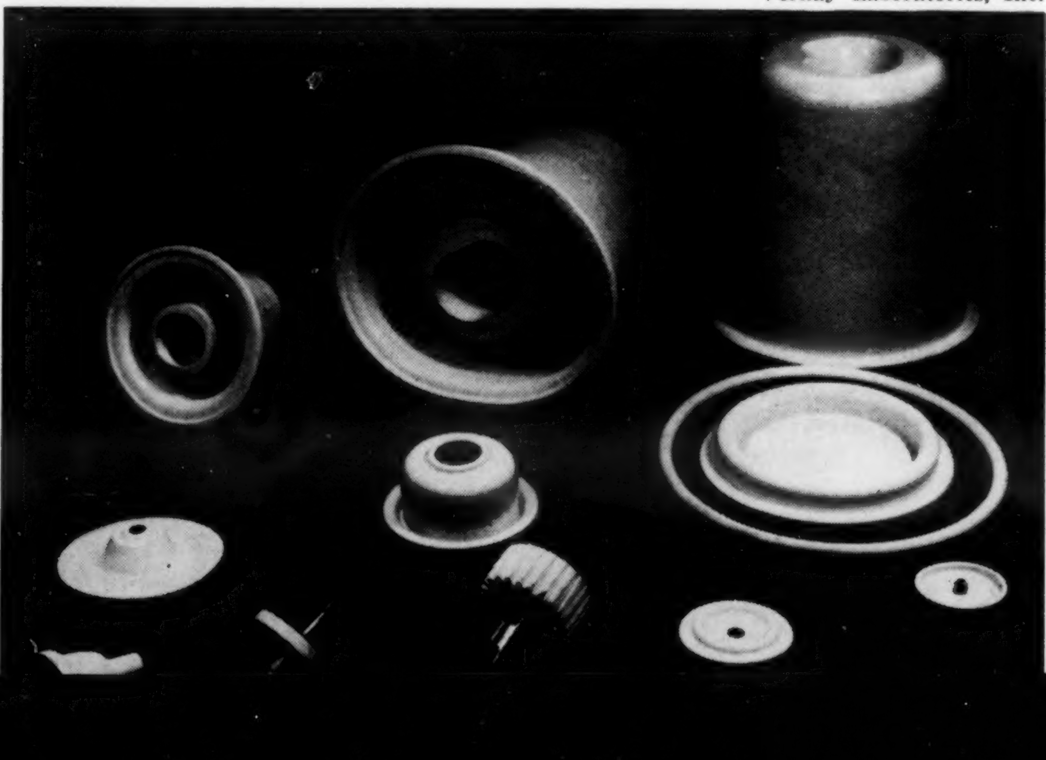
■ The important features of the fluoro-elastomers are resistance to fluids and extremes of temperature. Previously, silicones were the only elastomers usable in the 400 to 500 F range, and these had relatively poor resistance to many fluids encountered in aircraft and in chemical processing equipment. The fluoro-elastomers couple good thermal stability with good resistance to these fluids.

The five fluoro-elastomers are in varying stages of development (see box). Some are in extremely limited supply, and some are unobtainable as yet. This article gives the engineering information now available on each material—both to help in selecting an elastomer for present use, and to indicate what can be expected in the near future.

Kel-F Elastomer

There are two grades of Kel-F Elastomer: 1) grade 3700, the general purpose grade, with good mechanical properties, thermal stability, and resistance to fuels, lubricants and mineral acids; and 2) grade 5500, particularly recommended for exposure to strong oxidants, such as red and white fuming nitric acids. Blends of

Vernay Laboratories, Inc.



***Precision molded parts,** such as these diaphragms, o-rings and lip seals, can be produced in Kel-F Elastomer.*

grade 5500 and Kel-F Resin 800 offer maximum resistance to attack and penetration by these oxidants. A latex has also been developed recently and is available in limited experimental quantities.

The two most common Kel-F Elastomer compounds are grade 5500 with a peroxide cure, and grade 3700 with a HMDA (hexamethylene diamine) cure. Typical properties of these two vulcanizates are shown in Table 1.

The elastomer has good ozone and weather resistance. No change in physicals or appearance occurs after seven-day exposure in an oxygen bomb at 300 psi and 158 F. No change in physicals occurs and no surface defects appear during 6-hr exposure at 30% elongation. After 100-hr exposure to ultraviolet light in an Atlas Fadometer, there is a slight increase in tensile, but no change in elongation or hardness. After one-year outdoor exposure in an industrial atmosphere, no change in physicals occurs.

Mechanical properties

Among chemical and heat resistant rubbers, these elastomers are notable for tensile strengths of 1600 to 3500 psi, extensibility of 300 to 600%, and tear strengths of 150 to 400 lb per in. Modulus, hardness and tear strength of vulcanizates can be improved by use of fillers such as finely divided silica or carbon black. Effects of fillers in improving mechanical properties are shown in Table 2. Silica is especially useful in that it increases modulus, tear strength and hardness without appreciably affecting tensile strength or elongation. Silica-filled stocks show good retention of physical properties after air aging at 400 F. Also, silica's inherent chemical inertness and low moisture absorption make it attractive for chemical and electrical applications.

Fabric reinforcement such as cotton, nylon, polyester or tetrafluoroethylene, can give even greater mechanical strength than obtainable with fillers.

Heat resistance

Properly compounded, Kel-F Elastomers retain physical properties after prolonged aging at 400 F. Effects of temperature (without aging) on a high strength Kel-F Elastomer compound are compared with effects on several other rubbers in Fig 1. According to *Kitchen,* the higher strengths of Hevea (natural rubber) and Kel-F Elastomer in the lower temperature ranges, as compared with butyl and silicone, are at least partly due to crystallinity on stretching—an effect that seems to disappear entirely at temperatures above 300 to 400 F in Hevea and 200 F in Kel-F Elastomer.

In addition to the immediate effects of high temperatures, the effects of heat aging must be considered. Fig 2 shows effects of aging 8 hr at 350 F on room temperature tensile strengths of several elastomers. The saturated elastomers — Kel-F, urethane, butyl and silicone—all withstand heat aging very well, retaining two-thirds or more of original tensile strength. The unsaturated elastomers—Hevea and neoprene—show extensive heat deterioration and retain less than one-fourth of original strength.

Loss of strength due to the combination of instantaneous heat and heat aging is shown for several elastomers in Fig 3. Though, with the exception of Hevea, these are all heat-stable types, none has a tensile strength at 400 F as high as 500 psi after oven aging. Elongation of the heat aged Kel-F Elastomer at 400 F is intermedi-

A Summary of the Five Types[a]

Kel-F Elastomer

Produced by Jersey City Chemical Div., Minnesota Mining and Mfg. Co., the material is a copolymer of chlorotrifluoroethylene and vinylidene fluoride. The two grades are available commercially, and hold interest for —60 to 400 F applications, especially in contact with fuels. They are, to date, practically the only elastomers suitable for prolonged use with red fuming nitric acid (RFNA).

Silastic LS-53

Produced by Dow Corning Corp., the material is a fluoroalkyl silicone rubber. It is available in limited experimental quantities and is a medium low temperature, fuel resistant silicone rubber with a —90 to 400 F service range. It holds a great deal of interest for the Air Force, perhaps because it represents the first of the family of fluorinated silicones.

Fluoro-Rubber 1F4 and 2F4

Produced by Minnesota Mining and Mfg. Co., the materials are perfluorobutyl acrylate rubbers. 1F4 is a specification material available in pilot plant quantities. It retains useful rubbery properties from 12 to 450 F when exposed to diester type engine lubricants. Type 2F4 extends the lower temperature limit to —35 F, but as yet is an experimental material available only in limited quantities.

Viton A

Produced by E. I. du Pont de Nemours & Co., Inc., the material is a copolymer of vinylidene fluoride and perfluoropropylene. It is available in limited experimental quantities. It has outstanding high temperature fluid resistance, with a possible —65 to 600 F service temperature range. It may soon be an Air Force specification material for nearly all high temperature fluid applications.

Fluorinated polyester (no trade name)

Produced by Hooker Electrochemical Corp., the material is a hexafluoropentamethylene adipate. It is expected to be available in limited experimental quantities in the next few months. It has a —98 to 300 F temperature range in fuels and is an extreme low temperature material. It can be manufactured in a variety of molecular weights and may find extended use as an aircraft fuel tank sealant.

[a] Evaluations extracted from *Griffin.*

Properties of Kel-F Elastomer

Source: Jersey City Chemical Div., Minnesota Mining and Mfg. Co., except where noted

TABLE 1—TYPICAL PROPERTIES

Property	Grade 5500 (peroxide cure)	Grade 3700 (HMDA carbamate cure)
Stress at 100% Elongation, psi	500	1000
Tensile Strength, psi	2000	2700
Elongation, %	450	325
Hardness (Shore A)	55	58
Tear Strength, lb/in.	120	150
Compression Set, %		
70 hr at 158 F	45	23
70 hr at 300 F	60	35
Gehman Stiffness, F		
T_2	+32	+5
T_{10}	+23	0

TABLE 2—PROPERTIES OBTAINABLE WITH FILLERS[a]

Property	Original	Aged[b]
Stress at 300% Elongation, psi	800-1600	—
Tensile Strength, psi	1600-3600	725-1650
Elongation, %	250-500	550-800
Hardness (Shore A)	58-81	59-82
Tear Strength, lb/in.	120-500	—

[a]Range of values given indicates properties obtainable by using different proportions of different fillers.
[b]Seven days at 400 F.

TABLE 4—WATER ABSORPTION OF VARIOUS RUBBERS (77 F)

Type of Rubber	Days	Absorption mg/sq in.
Smoked Sheet	55	12.32
Neoprene	58	12.90
Deproteinized Rubber	63	6.38
Chlorosulfonated Polyethylene[a]	63	5.09
Kel-F Elastomer	**65**	**3.50**

[a]Hypalon.

TABLE 5—EFFECT OF MOISTURE ON ELECTRICAL PROPERTIES

Property	As Molded[a]	After Exposure[b]
Dielectric Strength		
Short Time, v/mil	613 (avg)	642 (avg)
Step-by-Step	521 (avg)	553 (avg)
Volume Resistivity, ohm-cm	1.13×10^{14}	1.21×10^{14}
Dielectric Constant		
60 cycles	6.27	6.52
1000 cycles	5.90	6.08
10^6 cycles	3.94	4.05
Power Factor		
60 cycles	0.025	0.028
1000 cycles	0.053	0.057
10^6 cycles	0.113	0.120

[a]Peroxide-cured.
[b]One week, 95% RH, 77 F.

TABLE 3—EFFECTS OF HIGH PRESSURE STEAM[a]

	Unfilled[b]			Filled[c]		
Exposure Time	None	1 Day	7 Days	None	1 Day	7 Days
Tensile Strength ,psi	1860	1060	1165	3800	1480	1200
Elongation, %	590	620	690	540	600	640
Hardness (Shore A)	51	42	42	68	69	69
Volume Swell, %	—	16	22	—	13	17

[a]Tests conducted at 400 F, 247 psi. [b]Stock number 89. [c]Stock number 122.

TABLE 6—CHEMICAL RESISTANCE[a]

Immersed in ...	Time, days	Temp, F	Vol Swell, %
ACIDS			
Fuming Sulfuric	27	77	1
Hydrochloric	27	77	16
Hydrofluoric (wet)	32	65	15, 12[c]
Phosphoric (85%)	27	77	1
Red Fuming Nitric	27	77	24
SOLVENTS			
Aniline	27	77	5, 13[c]
Carbon Tetrachloride	27	77	33, 16[c]
Cyclohexanone	1	77	700
Ethyl Alcohol	27	77	6
Ethylene Dibromide	15	77	5
Ethylene Glycol	27	77	1
Furfuryl Alcohol	27	77	4
Petroleum Ether	27	77	13
Toluene	27	77	55
Trichloroethylene	27	77	53
Turpentine	27	77	1
FUELS, LUBRICANTS			
ASTM Oil No. 1	27	77	0
ASTM Oil No. 2	27	77	1
ASTM Oil No. 3	27	77	1
Esso Turbo Oil 15	27	77	600[b]
70/30 Iso-Octane Toluene	27	77	30, 16[b]
JP-3	27	77	5
MLO 8200	20	300	8, 2[b]
OS-45 (hydraulic)	14	300	25
Silicone DC-200	7	300	1[b]
Skydrol W-46	14	300	70
Sour Crude	7	300	10[b]
Swan Finch GM-4655M	3	300	10[b]
Test Oil WA-389	3	300	5[b]
Texamatic 1505	27	77	1
UCON 50 HB-100	14	300	19
OTHER REAGENTS			
Bleach Solution	27	77	0.5
Chlorine Gas (1 atm)	7	77	2
Freon 113	1	77	180

[a]ASTM D-471, Method B.
[b]Results were obtained on grade 3700; all others on 5500.
[c]Results were obtained with polyamine cure; all others with peroxide.

ate—about 180%. The other elastomers have elongations as follows: Hevea, Hypalon, butyl, Viton A and polyacrylate—less than 100%; silicone rubber—240%; and urethane—130%.

Kel-F Elastomers have relatively low air permeability at room temperature compared with other rubbers. The effects of high temperatures are shown in Fig 4. In addition to thermal stability in air, vulcanizates resist high pressure steam (see Table 3).

Water absorption of Kel-F Elastomers is extremely low (see Table 4); consequently exposure to moisture has little effect on dielectric properties (see Table 5).

Fluid resistance

Kel-F Elastomers resist attack by strong oxidizing acids, mineral acids, peroxides, alkalis, alcohols, aliphatic solvents, some chlorinated solvents, hydraulic fluids, silicone oils and sulfur-bearing extreme-pressure lubricants. Typical test results are given in Table 6.

Effects of prolonged immersion in strong oxidizing agents on physical properties are shown in Table 7. Immersed in red fuming nitric acid, the elastomer reaches an equilibrium volume swell of 20 to 30% in one week. Extensibility and hardness remain virtually unchanged, though tensile strength decreases. Where maximum resistance to fuming nitric acid is required, the elastomer can be

TABLE 8—RESISTANCE TO HOT FLUIDS

Material[a]	Property	Original Value	Value After 70-Hr Immersion at 300 F in . . . ASTM No. 1	Socony Vacuum (WA-389)	Swan Finch (GM 4655-M)	Skydrol (W-46)	UCON (50-HB-100)	Aroclor (1254)	ASTM No. 4	Sour Crude	Silicone (DC-200)
Grade 3700 (unfilled)	Ten Str, psi	3500	4300	3100	2200	1860	1540	2900	2400	3200	4400
	Elong, %	500	560	590	580	520	575	480	450	460	440
	Hard. (Shore, A)	76	75	73	75	66	65	72	73	72	74
	Vol Swell, %	—	−4	+5	+10	+20	+22	+11	+18	+10	0
Grade 5500 (filled)	Ten Str, psi	3000	2800	2400	2200	400	1860	1500	1470	2350	3550
	Elong, %	570	700	700	670	>900	630	720	500	600	500
	Hard. A	72	69	68	73	35	69	69	73	69	71
	Vol Swell, %	—	0	+2	+10	+70	+19	+16	+20	+14	0

[a]Both peroxide-cured.

TABLE 7—EFFECTS OF CHEMICALS ON PHYSICAL PROPERTIES[a]

Chemical ➤	Red Fuming Nitric Acid	Fuming Sulfuric Acid	Aniline[b]
ORIGINAL PROPERTIES			
Ten Str, psi	1745	1600	1860
Elong, %	650	615	650
Hard. (Shore A)	53	52	55
AFTER 1-DAY IMMERSION			
Ten Str, psi	1460	2060	1725
Elong, %	620	720	670
Hard. (Shore A)	52	52	57
Vol Swell, %	9	0.5	0
AFTER 3-DAY IMMERSION			
Ten Str, psi	1050	2070	2075
Elong, %	450	730	700
Hard. (Shore A)	48	56	57
Vol Swell, %	19	1.5	0

[a]Tests conducted at room temperature.
[b]Effects of hydrogen peroxide quite similar to those of aniline.

blended with Kel-F Resin 800 (a copolymer having a different mole ratio than the elastomer). After three days immersion at room temperature a 50-50 rubber-resin blend retains 78% of original tensile strength compared to 32% for the pure elastomer; volume swell is only 10% compared with 25%.

The critical test for fluorinated elastomers is exposure to fluids at elevated temperatures. Table 8 shows the effect of 70-hr immersion in various fluids at 300 F. Fig 5 compares the effects of 75-hr immersion in JP-5 fuel on Kel-F Elastomers and Fluoro-Rubber 1F4. Despite its lower

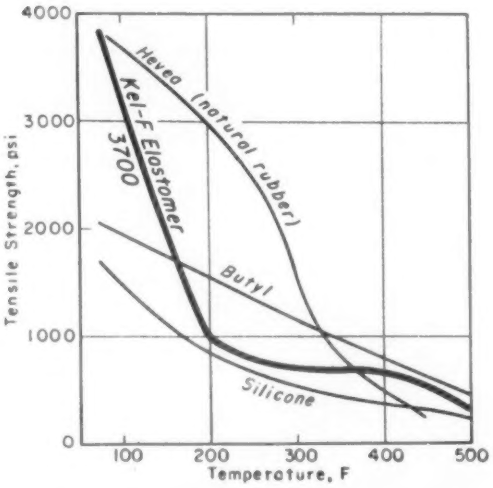


Fig 1—Tensile strength vs temperature for Kel-F Elastomer compared with other rubbers. (Kitchen)

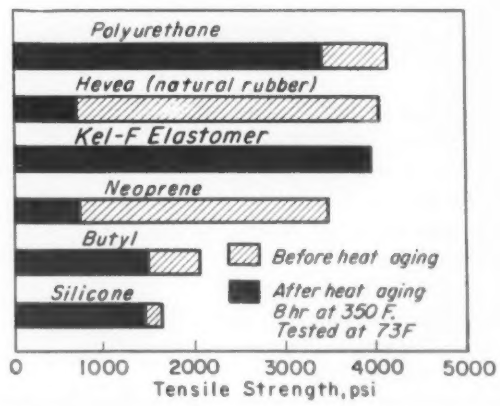


Fig 2—Effect of heat aging on Kel-F Elastomer compared with several other rubbers. (Kitchen)

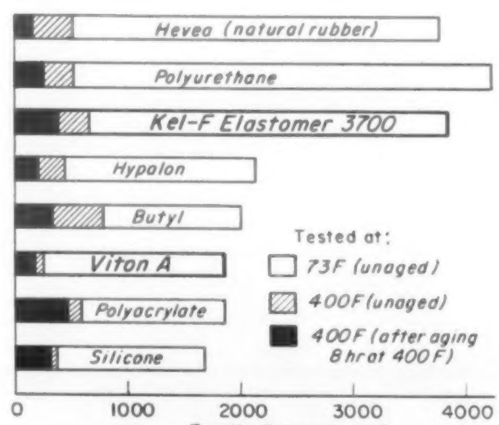


Fig 3—Effects of temperature and aging at temperature on Kel-F Elastomer, Viton A and several other rubbers. (Kitchen)

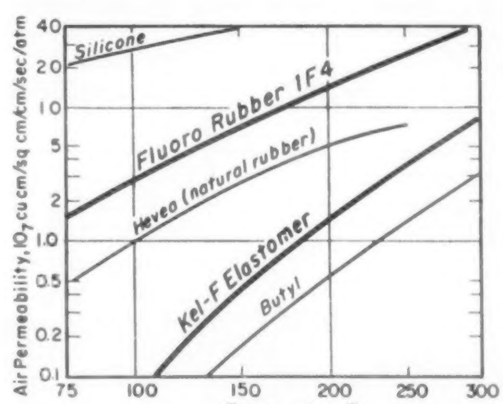


Fig 4—Air permeability vs temperature for Kel-F Elastomer, Fluoro-Rubber 1F4 and several other rubbers. (Kitchen)

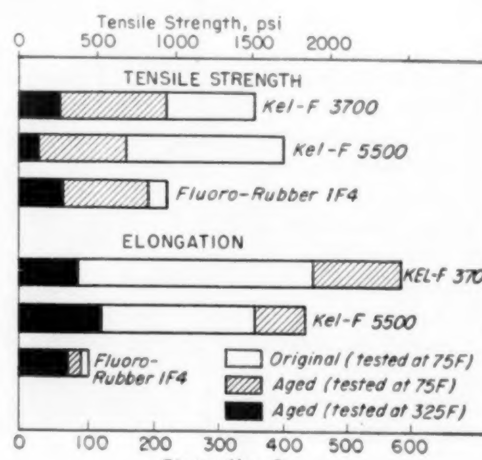


Fig 5—Effect of temperature and aging at temperature on tensile strength and elongation of both grades of Kel-F Elastomer and of Fluoro-Rubber 1F4. (Fujiwara)

original strength, 1F4 after aging is comparable to Kel-F 3700 and superior to Kel-F 5500 when tested at both 75 F and 325 F. According to *Fujiwara* and *Spain*, however, recent work indicates that Kel-F 3700 can be compounded to provide aged properties considerably better than those of 1F4.

Applications

In general, the properties of grade 3700 elastomer suggest its use in seals for hot hydraulic fluids, transmission oils and EP lubes; seals and hose for hot JP fuels; and hose, pump and valve diaphragms and gaskets for hot mineral acids or alkalis. Properties of grade 5500 and blends of 5500 with copolymer resins suggest their use in hoses, seals, diaphragms, fuel cells, protective clothing, and barriers for chromic and fuming nitric acids. Both grades of the elastomer seem suitable for high temperature electrical insulation involving exposure to oxidants, fuels, oils and mineral acids.

Properties of Silastic LS-53

Source: Dow Corning Corp., except where noted

TABLE 9—TYPICAL PROPERTIES[a]

Color	Red
Specific Gravity	1.4
Hardness (Shore A)	55
Tensile Strength, psi	1000
Elongation, %	170
Compression Set (after 22 hr at 300 F), %	20
Brittle Point, F	−90
Linear Shrinkage, %	3
Water Absorption (70 hr at 212 F)	
Durometer Change	−2
Volume Change, %	+3

[a]Specimens molded 5 min at 260 F and cured 24 hr at 300 F, except for specific gravity specimen which was press vulcanized.

TABLE 10—CHEMICAL RESISTANCE[a]

Chemical ▼	Time, Temp[b]	Dur Hard. Chg	Vol Chg, %
Acetone	7, 75	−21	+181
Aniline	7, 75	− 1	+4
ASTM Oils			
No. 1	3, 300	− 4	Nil
No. 3	3, 300	− 6	+4
No. 3	21, 300	− 9	+3
No. 3	3, 400	−14	+5
Carbon Tetrachloride	7, 75	− 6	+21
Ethyl Alcohol	7, 75	− 2	+5
Hydraulic Fluid			
(MIL-O-5606)	1, 160	− 6	+6
Jet Fuels	19, 250	−11	+6
ASTM Ref B	3, 75	− 6	+20
	3, 158	− 6	+18
	1, 75	− 5	+11
	14, 75	− 5	+10
	15, 250	−18	+18
Nitric Acid (10%)	7, 75	+ 2	+1
Nitric Acid (conc)	7, 75	+ 1	+4
Orthochlorotoluene	7, 75	− 6	+19
Phosphate Ester	3, 250	−36	+8
	3, 300	c	c
Power Trans Fluid			
(Ord 51-F-21)	3, 300	− 9	+11
SAE No. 10 HD	3, 300	− 4	+2
Silicate Ester	3, 350	−13	+6
Silicate Ester with Diester	3, 350	−12	+9
Sodium Hydroxide (10%)	7, 75	− 4	−2
Sodium Hydroxide (50%)	7, 75	− 4	+1
Sulfuric Acid (10%)	7, 75	Nil	Nil
Sulfuric Acid (conc)	7, 75	c	c
Xylene	3, 75	− 9	+19
	3, 158	− 8	+21

[a]High temperature tests with volatile materials were run under reflux conditions.
[b]Time in days; temperature in deg F.
[c]Deteriorated.

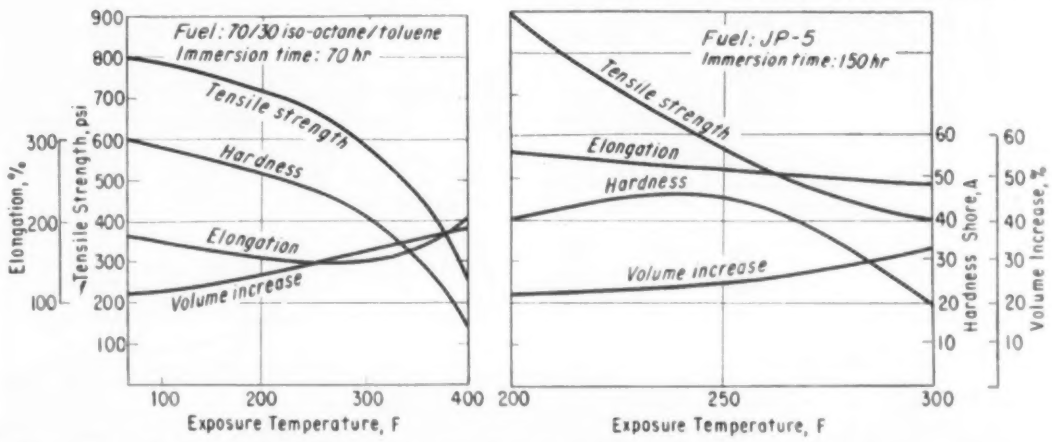


Fig 6—*Effect of fuels on Silastic LS-53 at elevated temperatures.* (Griffin)

TABLE 11—EFFECTS OF HOT FLUIDS[a]

Exposed in . . . ▼	Exposure Temp, F	Ten Str Change, %	Elongation Change, %	Hardness Change, %	Volume Change, %
Air	500	−40	+18	− 5	− 2
Hydraulic Fluids					
G-E 81406	400	−28	+14	−27	+14
	500	−85	+30	−54	+ 2
OS 45	400	−85	+18	−54	+12
85/15	400	−87	+32	−68	+11
Diester Lubricant(Anderol L774)	400	−50	+20	−40	+10

[a]Material tested at room temperature after 70-hr exposure at temperature indicated. Source: *Griffin*.

Silastic LS-53

Incorporation of fluorine in silicone rubber adds resistance to swelling in fluids to the good temperature stability of silicone rubber. Properties of the elastomer were summarized in "New Heat and Solvent Resistant Elastomer," MATERIALS & METHODS, Nov '56, p 163; "Selecting Silicone Rubbers", M&M, May '57, p 140 (Part 1); and M&M, June '57, p 114 (Part 2).

Table 9 shows typical physical properties of the elastomer, and Table 10 shows additional data on resistance to chemicals and fluids at room and elevated temperatures. Fig 6 and Table 11 show the effects of hot fluids on mechanical properties.

By way of comparison, o-rings made of fluoro-silicone rubber swelled 20% when immersed in ASTM Reference Fuel B for 70

TABLE 12—TYPICAL PROPERTIES

Type ➤	1F4	2F4
Tensile Strength, psi		
77 F	1250, 1210[a]	950
212 F	600	—
250 F	470	—
Ultimate Elongation, %		
77 F	300, 200[a]	300
212 F	180	—
250 F	155	—
Mod at 100% Elongation, psi	280, 500[a]	—
Hardness (Shore A-2)	55, 65[a]	65
Set at Break, %	9	—
Resilience (Bashore), %	6	—
Compr Set (Method B)		
70 hr at 212 F	53, 18[a]	—
70 hr at 250 F	28[a]	55
Low Temp Flexibility[b]		
Gehman T_{10}, F	+12, +12[a]	—
ASTM Brittle Point, F	+9, +9[a]	−37

[a]Oven tempered 24 hr at 300 F.
[b]Service tests have shown elastomer retains some flexibility as low as −10 F. Service tests are, therefore, recommended for applications in this temperature range.
Source: *Griffin* and Minnesota Mining and Mfg. Co.

TABLE 13—GENERAL CHEMICAL RESISTANCE

	Time, days	Temp, F	Vol Chg, %
Aliphatic Hydrocarbons	14	77	0-10
Aromatic Hydrocarbons	14	77	15-30
Aromatic Hydrocarbons	2	212	30-50
Alcohols	14	77	0-10
Ketones	14	77	35-85
Chlorinated Solvents	1-2	77	20-40
Some Specific Chemicals			
Ethyl Acetate	14	77	+100
Freon 12	3	77	+155
Freon 22	3	77	+215
Sodium Hydroxide (10%)	14	77	+190

hr; conventional silicone rubber rings swelled 200%.

The elastomer has good strength, is resistant to compression set, and is serviceable from -80 to 500 F in air. Samples aged 1000 hr at 480 F do not break when flexed 180 deg over a 3/8-in. mandrel, and hardness increases only nine points. Fillers provide a harder stock and do not affect solvent and oil resistance.

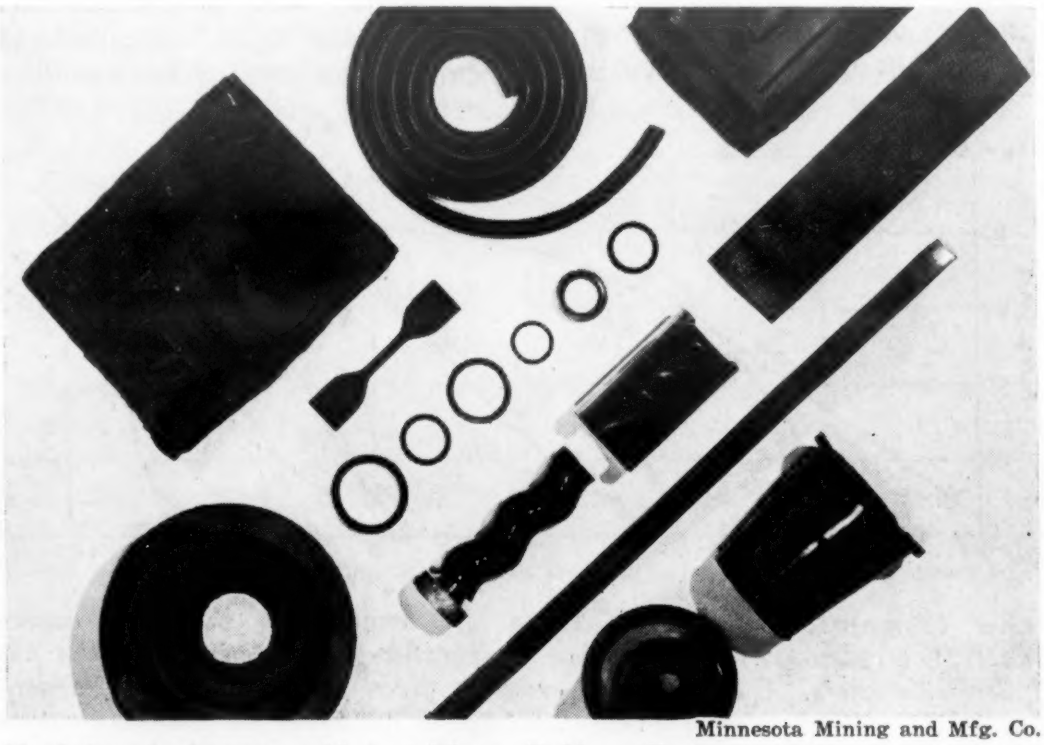
Properties of Fluoro-Rubber 1F4 and 2F4

Source: Minnesota Mining and Mfg. Co., except where noted

TABLE 14—RESISTANCE TO ACIDS, HYDRAULIC FLUIDS AND OILS

Fluid ▼	Time, hr	Temp, F	Change in Properties			
			Ten Str, %	Elong, %	Hardness, pts	Vol, %
ACIDS						
Hydrochloric (10%)	70	212	−1	−41	+15	+11
Nitric (10%)	70	212	−57	+24	−8	+35
Sulfuric (10%)	70	212	0	−65	+26	0
White Fuming Nitric (90%)	3	77	−60	−12	−30	+74
....	250	77	−77	+26	−50	+35
....	1000	77	−75	+310	−54	+27
HYDRAULIC FLUIDS, OILS						
Calif. Research Oil 52742	100	212	−14	−34	+10	0
......	—	300	−46	−46	+15	+3
Cellulube 300	100	350	−7, −5[a]	−58, 0[a]	+15, −5[a]	—
......	—	400	−17, −31[a]	−62, −24[a]	+20, 0[a]	—
Cities Service A	100	300	−22	−55	+20	0
......	—	350	−59	−86	+25	−2
......	775	350	[b]	[b]	+48	−9
Delco No. 11	168	158	−40	−45	−5	+10
MIL-L-7808	500	350	+19, +20[a]	−66, −17[a]	+25, +13[a]	0, +6[a]
MIL-O-5606	500	350	+11, −51[a]	−72, −57[a]	+27, +18[a]	0, 6[a]
......	—	400	—	—	+43, +36[a]	−3
MLO-8200	100	350	−32	−37	+13	—
......	24	500	−82	0	+10	—
Pyranol Transformer Oil	1000	212	−20	−45	−5	+5
......	100	300	−30	−40	+5	+3
......	½	455	−10	−30	−5	—
Shell No. 5	70	250	−5	−45	+5	0
Skydrol 500	100	212	−35	−45	−15	+25
Socony-Vacuum WA-389	70	300	−10	−50	+15	0
Swan-Finch GM-4655-M	70	300	−10	−65	+15	−5
Versilube F-50	100	350	−46	−53	+26	—
......	—	400	−73	−80	+30	—
......	24	500	−77	−93	+38	—

[a]Tempered vulcanizate.
[b]Too brittle to measure.



Minnesota Mining and Mfg. Co.

***Variety of shapes** molded of Fluoro-Rubber 1F4.*

Fluoro-Rubbers 1F4 and 2F4

These elastomers are intended for continuous use at temperatures up to 400 to 450 F and intermittent use at higher temperatures. The major difference between the two, as can be seen in Table 12, is that the brittle point of 2F4 is 40 to 50 deg F lower than that of 1F4.

Permeability of a 17-mil membrane of 1F4 to white fuming nitric acid (90%), as determined in modified Navy H-cell equipment, was 20 min. A 50-mil film lengthened the time to 2 hr. Effects of high temperatures on air permeability of type 1F4 are shown in Fig 4.

The elastomers are said to be essentially immune to ozone attack. Strips bent in a 180-deg arc or extended 25% show no signs of cracking or other damage after one-week exposure to circulating air containing 350 ppm of ozone by volume at room temperature.

These fluoro-elastomers have good resistance to a variety of fluids, including jet fuels and other petroleum products, silicate esters and many solvents. Particularly valuable is their resistance to synthetic diester type lubricants. General chemical and fluid resistance of type 1F4 are shown in Tables 13 and 14. Fig 5 shows the effect of immersion in hot JP-5 jet fuel.

Viton A

Typical properties of Viton A at room temperature and at 300 and 400 F are shown in Table 15. Tensile strength and elongation drop progressively as temperature increases, but there is little further reduction in properties above 400 F. Fig 3 compares room temperature tensile strength with instantaneous tensile strength at 400 F and tensile strength after aging 8 hr at 400 F.

More important in certain applications such as o-ring seals is Viton A's good resistance to compression set and deformation at high temperatures. Typical values for compression set (ASTM Method A, 400 psi) after 22 hr at 400 F are 35-55% deflection and 15-23% set. Tested by Method B (25% deflection, 70 hr), vulcanizates show 25% set at 250 F, and 45% set at 350 F.

Reduction in tensile strength and elongation at elevated temperatures is a reversible effect and does not indicate deterioration. Effect of temperature on estimated service life, is shown by the following data, expressed in hours to produce brittleness at each temperature:

400 F	< 2400 hr
450 F	1000 hr
500 F	250 hr
550 F	72 hr
600 F	8 hr

Though under ordinary handling conditions Viton A and its vulcanizates present no health hazards, some decomposition products are highly toxic. Decomposition usually starts at temperatures approaching 500 F. When handling the material at these temperatures, work areas should be adequately ventilated.

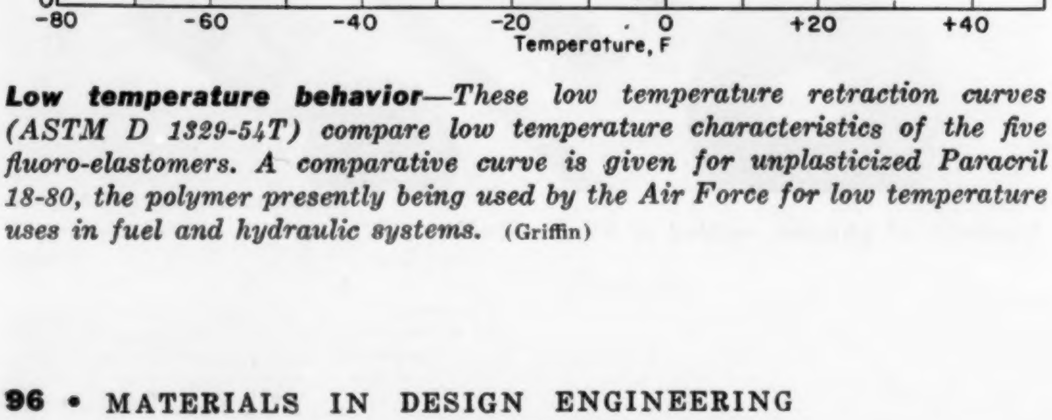
The brittle point of the elastomer is dependent on thickness of specimens. For example, the –47 F value shown in Table 15 was obtained on a 0.075-in. specimen. A 0.025-in. specimen of the same formulation has a brittle point of –60 F, and a 0.010-in. wire coating does not crack at –90 F when bent around a mandrel 10 times the wire diameter. Small amounts of oil absorbed during service improve low temperature flexibility.

Fluid resistance

In general, Viton A is more resistant to more fluids than any known elastomer today. It is resistant to aromatic and aliphatic hydrocarbons, aromatic amines, chlorinated hydrocarbons, dilute and concentrated mineral acids and alkalis, petroleum hydrocarbons and water. Highly polar materials, in general, cause the most swelling; swelling in the nonflammable hydraulic fluids, such as Pydraul, Lindal and Skydrol, is excessive. Examples of fluids that cause "high swell" and "low swell" of Viton A are listed in Table 16. Effects of immersion in JP-5 fuel at 400 F are shown in Table 17. Table 18 shows the changes in mechanical properties caused by exposure to various fluids at high temperatures.

Radiation resistance

Though most elastomers have



Low temperature behavior—*These low temperature retraction curves (ASTM D 1329-54T) compare low temperature characteristics of the five fluoro-elastomers. A comparative curve is given for unplasticized Paracril 18-80, the polymer presently being used by the Air Force for low temperature uses in fuel and hydraulic systems.* (Griffin)

Properties of Viton A

Source: E. I. du Pont de Nemours & Co., Inc., except where noted

TABLE 15—TYPICAL PROPERTIES

Modulus at 100% Elongation, psi	
77 F	300
300 F	100
Tensile Strength, psi	
77 F	2375
300 F	450
400 F	220
Elongation, %	
77 F	350
300 F	225
400 F	60
Hardness (Shore A, 77 F)	66
Resilience, %	
77 F	43
300 F	63
Brittle Point, F	−47
Gehman T_{10}, F	−7
Volume Resistivity, ohm-cm	10^{13}
Power Factor, %	3-4
Dielectric Strength, v/mil	250-750

TABLE 16—EFFECT OF FLUIDS

LOW SWELL FLUIDS (<25%)	
ASTM No. 3 Oil, 350 F	Nitric Acid (90%), 77 F
ASTM Ref Fuel B, 75 F	Oronite 8515, 400 F
JP-4, 400 F	OS-45-1 Oil, 400 F
Turbo Oil No. 15, 400 F	
HIGH SWELL FLUIDS (>100%)	
Ethyl Acetate, 75 F	Propyl Nitrate, 75 F
Glacial Acetic Acid, 75 F	Skydrol 500, 300 F

TABLE 17—EFFECT OF AGING IN HOT JP-5

Property ➤	Ten Str, psi	Elong, %
Original[a]	1850	230
Heated to 400 F in JP-5[b]	310	120
Aged 72 Hr at 400 F in JP-5[b]	280	140

[a]Tested at 75 F. [b]Tested at 400 F.
Source: *Fujiwara.*

TABLE 18—EFFECT OF HIGH TEMPERATURES AND FLUIDS[a]

Exposed to . . . ▼	Time, hr	Temp, F	Ten Str Change, %	Elongation Change, %	Hardness Change, %	Volume Change, %
Air	70	550	−38	−57	+30	−15
70/30 Isooctane/Toluene	70	400	−38	0	−30	+31
JP-5	70	400	−17	0	−12	+ 4
Hydraulic Fluid OS 45-1	5	550	−17	−19	−10	+1.5
MIL-0-8200	5	550	−55	−62	+10	+0.5

[a]Tested at room temperature.
Source: *Griffin.*

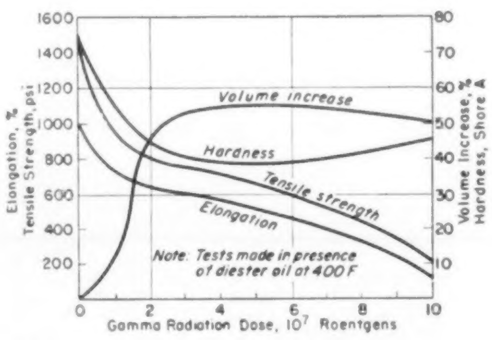


***Fig 7**—Radiation resistance.* (Griffin)

poor resistance to gamma irradiation, Viton A seems quite promising after limited testing. Fig 7 shows the effect of irradiation on mechanical properties. To more closely simulate conditions that might be encountered in nuclear powered aircraft, tests were carried out in the presence of diester oil at 400 F. After 10^8 Roentgens exposure, tensile strength is 220 psi and elongation is 120%. According to *Griffin*, Viton A resists radiation at high temperatures better than any elastomer known to the Air Force.

Applications

A field evaluation program now in progress in cooperation with Wright Air Development Center should provide data on actual use. Potential uses:

1. O-ring seals and packings are being tested in hydraulic, fuel and lubricant systems. Excellent performance at high temperatures and pressures under rapid cycling has been reported.

2. Cellular sealing strips for hatch gaskets for use at 500 F look promising.

3. Development of bladder-type fuel cells is in preliminary stages, and there are indications that a cell satisfactory for service at 500 F can be developed. However, the problems of diffusion of fuel and control of corrosive by-products of the elastomer given off at 500 to 600 F remain to be solved.

4. High pressure hose is a potential application because of the elastomer's heat and fluid resistance.

5. Dielectric properties (see Table 15) suggest such uses as insulation for hook-up wire and other low voltage, low frequency applications. Though insulated wire has been tested electrically, no simulated service tests have been completed.

6. Caulking compounds, protective coatings and adhesives can be produced from solvent solutions of the elastomer. Good resistance to heat and fluids can be expected where shrinkage due to loss of solvent can be tolerated.

Fluoro-polyester

General characteristics of the fluorinated polyester elastomer include: good mechanical properties; thermal stability in air at 400 F; resistance to fuels and fluids, including diester oil, at 350 F; and excellent low temperature usefulness, as indicated by a brittle temperature of −98 F and a Gehman T_{10} of −62 F (see Table 19). Tensile strengths of most compounds range from above 2000 psi to as high as 3000 psi in some cases. Corresponding elongations range from 100 to 300%, and up to 500% in some cases. Hardness can be varied from 50 to 90 Shore A, with values between 60 and 80 most common.

After 168-hr immersion in various fluids at room temperature (see Table 20), little change

Properties of fluoro-polyester elastomer

Source: Hooker Electrochemical Co., except where noted

TABLE 19—LOW TEMPERATURE PROPERTIES[a]

Torsional Modulus (77 F), psi	188
Gehman, F	
T_2	−42
T_5	−56
T_{10}	−62
T_{100}	−72
Freeze Point, F	−71
Brittle Temperature, F	−98

[a]Tests performed at B. F. Goodrich Co. on 0.075-in. specimens.

TABLE 20—RESISTANCE TO FUELS AND FLUIDS[a]

Fluid	Jet Fuel	70/30 Iso-Octane/Toluene	Diester Oil (Plexol 201)	HCl (10%)	NaCl (10%)
Tensile Strength, psi	2950	2217	1888	2700	1756
Elongation at Break, %	325	475	425	500	500
Set at Break, %	1-2	1-2	1-2	1-2	1-2
Modulus at 300% Elongation, psi	2565	750	—	750	574
Hardness (Shore A)	69-72	57-62	54-58	57-62	54-59

[a]168-hr immersion at room temperature; 0.025-in. dumbbell specimens of variously compounded vulcanizates.

TABLE 21—EFFECT OF HIGH TEMPERATURE AND DIESTER OIL[a]

Property ➤	Ten Str, psi	Elong, %	Set at Break, %	Hard. (Shore A)	Vol Swell, %
Original	2000-2200	110-150[b]	0-2	75-80	—
Aged (168 hr at 400 F in air)	1400-1600	130-175	5-8	72-80	—
Aged (70 hr at 350 F in Plexol 201 diester oil)	1500-1700	150-200	5-8	68-75	1-3

[a]Tests performed on 0.025-in. dumbbell specimens.
[b]Postcure will increase original elongation.

in tensile strength or other physical properties occurs. Of all fluids tested, aromatic gasoline (70/30 iso-octane/toluene) causes the greatest swelling—about 10 to 20%, depending on compounding. Both JP-4 jet fuel and synthetic diester oil cause very slight swelling, and 10% hydrochloric acid and salt solution scarcely affect the rubber.

Effects of high temperature and immersion in diester oil on mechanical properties are shown in Table 21. In both cases vulcanizates retain tensile strengths of 1400 to 1700 psi, with little or no decrease in elongation or hardness.

References

Much of the information for this article was extracted from the following papers presented at the Elastomers for Air Weapons Conference sponsored by Materials Laboratory of Wright Air Development Center, Mar '57:

Fujiwara, E. J., and Spain, R. G., "Compounds for High Temperature Seals and Their Testing Under Simulated Use Conditions."

Griffin, W. R., "WADC Evaluation of Experimental Polymers."

Hamlin, H. C., "Rubber—The Achille's Heel."

Kitchen, L. J., "High Temperature Aircraft Tires."

Postelnek, W., "Air Force Polymer Development Program."

Rugg, J. S., "Viton A—Its Application in Air Weapons."

Acknowledgments

The author would like to thank in particular Dr. G. C. Schweiker of Hooker Electrochemical Co. who prepared the bulk of the material on the fluorinated polyester elastomer, and E. R. Bartholomew, and R. Headrick of Materials Laboratory of Wright Air Development Center for assistance in obtaining source material and for reviewing the manuscript.

The assistance of personnel and literature of the following companies is also greatly appreciated:

Dow Corning Corp.
E. I. du Pont de Nemours & Co., Inc.
Hooker Electrochemical Co.
Minnesota Mining and Mfg. Co.

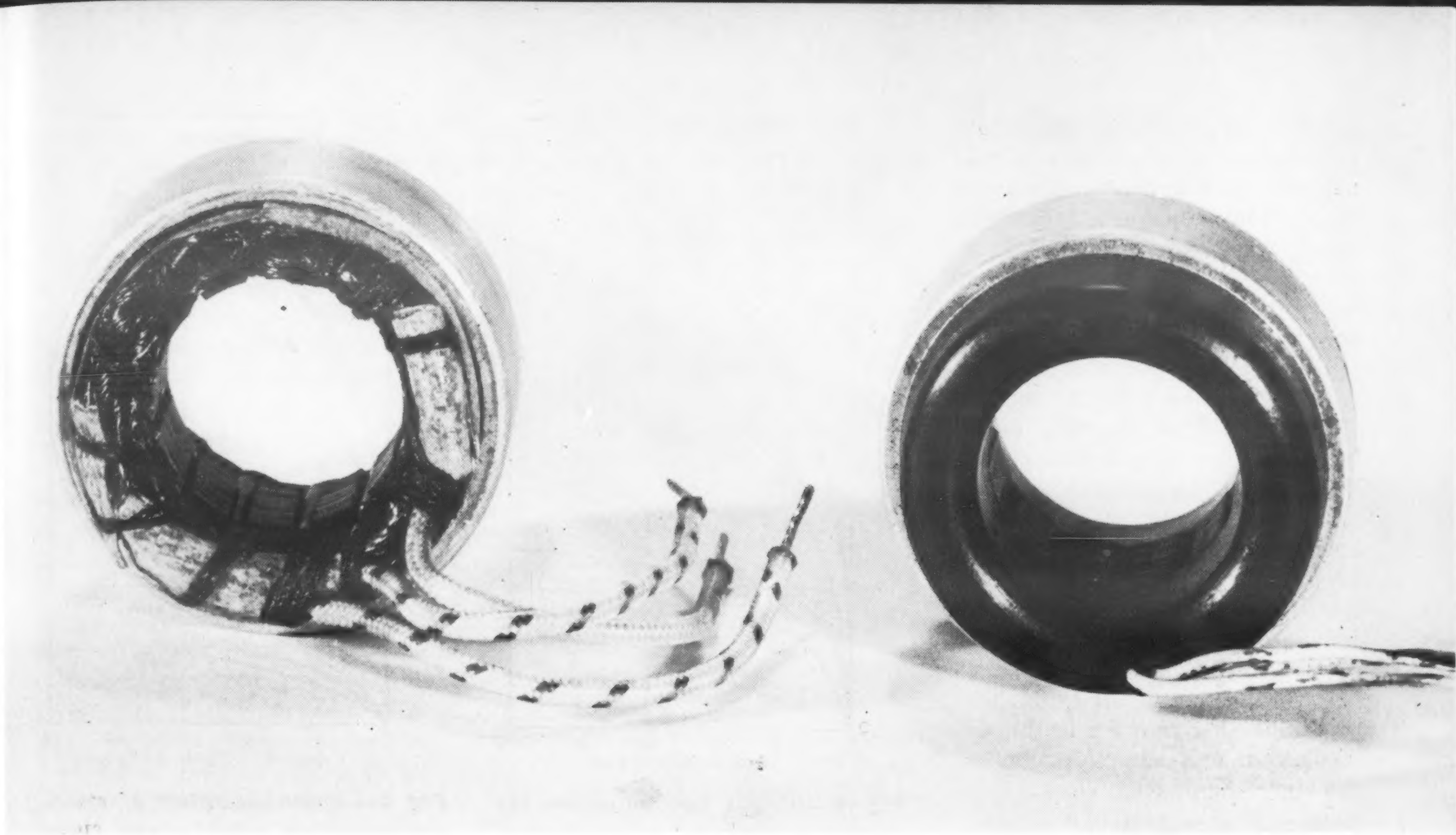
The Problem of Elastomers

The design engineer interested in elastomers that will meet critical service conditions keeps his eye on aircraft elastomer developments. In only a few years the environmental temperature range for air weapon systems and their components has expanded from the —65 to 275 F range to the —130 to 400 or 500 F range. According to the Air Force an environmental range of –400 to 2000 or 3000 F can be considered for tomorrow.

Compounding these high and low temperature problems as far as elastomers are concerned is the additional requirement of resistance to attack by such media as hydrocarbon fuels, lubricants, hydraudic fluids, and nuclear or cosmic radiation at these temperatures.

The fluoro-elastomers are the newest rubbers developed to meet present-day requirements. They are in varying stages of development, but all have reached the point of initial, evaluation, and their performance can be predicted with some degree of reliability. The materials are extremely promising for today's aircraft and for many commercial applications where temperature and fluid resistance are critical. However, they have already become almost obsolete as far as tomorrow's aircraft are concerned.

As for the more critical demands of the future, the solution will probably lie in designing without elastomers, or in the development of inorganic elastomers. Several inorganic systems have been experimented with; the most promising from the standpoint of thermal stability are the boron-phosphorus, nitrogen-phosphorus and chelate polymer systems. Increased Air Force research emphasis is being placed on development of such systems, but the operative inorganic elastomer is still a long way off.



OLD **NEW**

Uncluttered appearance *of redesigned stator is apparent in this side-by-side comparison of old and new designs.*

Cast Epoxy Insulation

Makes a Better Stator

Use of a filled epoxy resin plus a vacuum casting process has considerably improved the performance of an electric motor stator with no increase in manufacturing costs.

by D. E. Crawford,
General Electric Co.

■ Cast insulation systems have improved the design and performance of numerous electrical and electronic components. Selection of a cast insulation in itself, however, is not a guarantee of improved product design. Every product is unique, and the purpose of this article is to show how the performance and production of a typical electrical component—in this case a small motor stator—was improved by a carefully coordinated resin and process development program.

Why redesign?

As shown in the photograph above, this motor stator had been insulated and constructed in a completely conventional manner. The standard method of insulating the stator consisted of wedging the coils in the laminations, tying and forming the coils, and then insulating the assembly with several coats of an insulating varnish. This is by no means a poor insulation system; however, it does have a number of drawbacks. They include: 1) the large

number of assembly operations and resulting high labor costs; 2) subjection of unprotected stators to handling damage; 3) complicated masking and cleanup required for varnish dipping; and 4) long baking cure required for the insulating varnish.

Because of these shortcomings it was reasoned that the conventional insulation system might best be replaced by a cast insulation system. In addition to eliminating the above disadvantages, this system could be expected to: 1) provide a much higher dielectric strength; 2) be more suitable for mass production; and 3) lower costs by eliminating slot wedges and the need for coil tying, and by facilitating changes in the slot insulation and simplification of the stator lamination stack.

Selection of materials

The first step in the redesign was to choose the material that could best meet the expected operating and environmental conditions. Some of the requirements were particularly severe, since the component had to meet military specifications.

Properties of the three most promising insulation systems (including varnish) are compared in the accompanying table. Of all the properties required of a material for this and similar applications, low weight loss at high temperatures and ability to withstand rapid temperature changes are the most important.

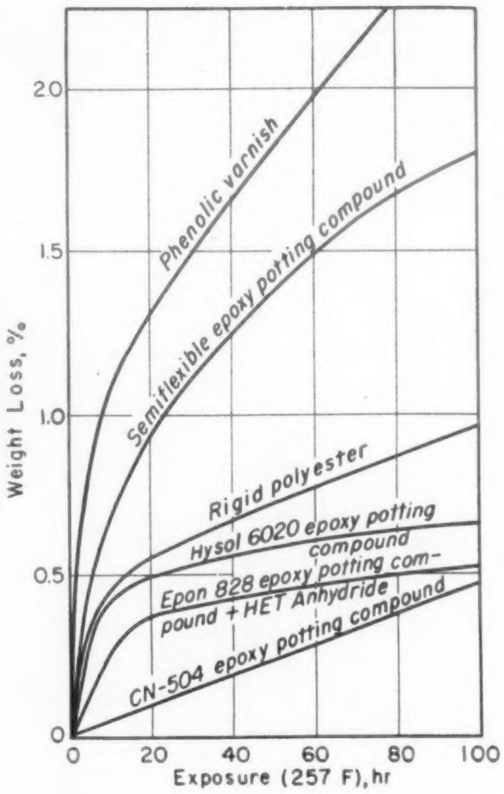


***Fig 1**—Weight loss measurements of various insulating materials show thermal stability of epoxy casting resins.*

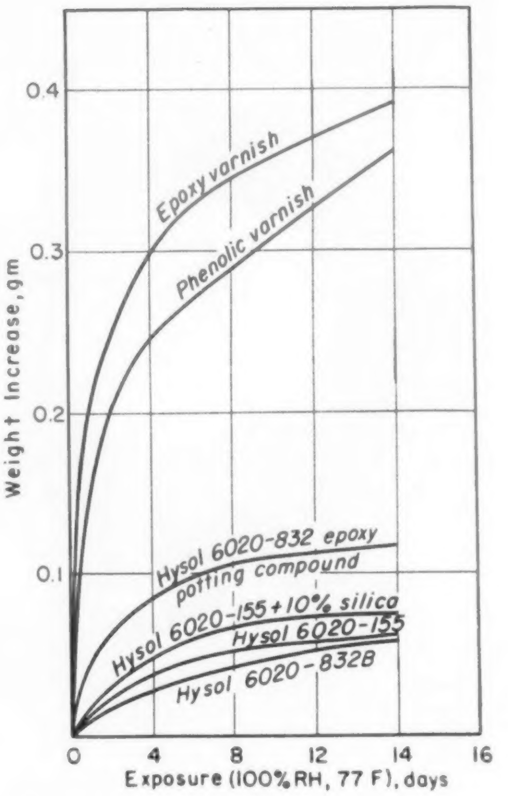


***Fig 2**—Water absorption of standard insulating varnishes and epoxy casting resins.*

Weight loss—This is a general measure of a material's thermal stability. As shown in Fig 1, epoxy casting resins proved to be superior to polyester resins and varnishes in two significant respects. The total weight loss is less for an epoxy resin after a given exposure, and the rate of weight loss is considerably less than for other materials after 24 hr of aging. Also, the weight loss is at least 25% less in the cast epoxy stator than in the varnished stator despite the fact that there is nearly 10 times more resin in the cast stator.

In addition to low weight loss at high temperatures, epoxy casting resins also exhibit a low increase in weight after exposure to moisture-laden atmospheres. As shown in Fig 2, epoxy potting compounds show considerably less increase in weight than standard epoxy and phenolic varnishes after exposure to 100% relative humidity for several days.

Temperature cycling—Probably the most difficult environmental condition that electrical equipment of this type must meet is dictated by military requirements that call for operation at temperatures from –85 to 257 F. In this range, the strains caused by thermal expansion are high enough to rupture an insulation system. This problem can be mitigated by selecting a flexible or semiflexible resin, or else by modifying rigid insulations with appropriate fillers to lower their coefficient of expansion. Because of the high weight loss of the flexible resins, the latter approach proved to be the most acceptable.

A number of resin-filler combi-

PROPERTIES OF MATERIALS CONSIDERED FOR STATOR INSULATION

Property Required ▼ Insulation ➤	Varnish	Epoxy	Polyester
Low Weight Loss After Curing	No	Yes	Fair
Suitability for Operation from – 85 to 257 F	Yes	Development needed	No
Low Shrinkage after Curing	Not applicable	Yes	No
Indefinite Life at Class A Temperatures	Yes	Yes	Yes
Short Cure at 212 F or Lower	No	Yes	Yes
Minimum Pot Life of 3 Hr	Yes	Development needed	Yes
Minimum Dielectric Strength of 300 V/Mil	Yes	Yes	Yes
Low Power Factor	Yes	Yes	Yes
Freedom From Heat Distortion	Yes	Yes	Yes
Suitable Strength to Withstand Vibration	Yes	Yes	Yes
Little or No Cleanup	Unsuitable	Yes	Yes
Ease of Mold Release	Not applicable	Fair	Good
Low Moisture Absorption	No	Yes	Yes
Good Adhesion to Adjoining Surfaces	Yes	Yes	No

nations were evaluated by cycling them as follows: 2 hr at –85 F, 10 min at room temperature, 2 hr at 257 F, and 10 min at room temperature. Of all the materials evaluated, a standard epoxy potting compound (Hysol 6020) with either slate or quartz fillers appeared to be the most resistant to cracking.

Selection of casting process

In parallel with the materials development program, process development was conducted to determine the most satisfactory method of casting the stators.

Centrifugal casting—Because of its relative simplicity, initial development centered around the centrifugal casting process. Results with this process proved to be variable. Despite efforts to fill the mold at various speeds and in various positions, bubbles appeared at the top of the stator casting during the curing operation. These bubbles are believed to have been trapped in the casting during centrifuging, and released during curing when they expanded because of the heat and the decrease in resin viscosity. Further investigation showed that these bubbles could be eliminated by treating the stators in a vacuum before casting. However, because of its complication, this combination vacuum-centrifugal process was discarded in favor of an all-vacuum casting technique.

Vacuum casting—Successful application of vacuum casting to this design hinged on the solution to three important problems: 1) placement of the parting line; 2) developement of simple and foolproof seals that would keep the mold vacuum-tight; and 3) development of a method to keep the pole faces clear and free of resin. As shown in Fig 3, these problems were solved by using an expandable center plug in the stator bore which seals the inner face of the mold vacuum-tight and which, when squeezed, expands to seal the pole faces from the resin (see Fig 4). A similar seal on the outside of the stator seals the top and bottom molds from the atmosphere.

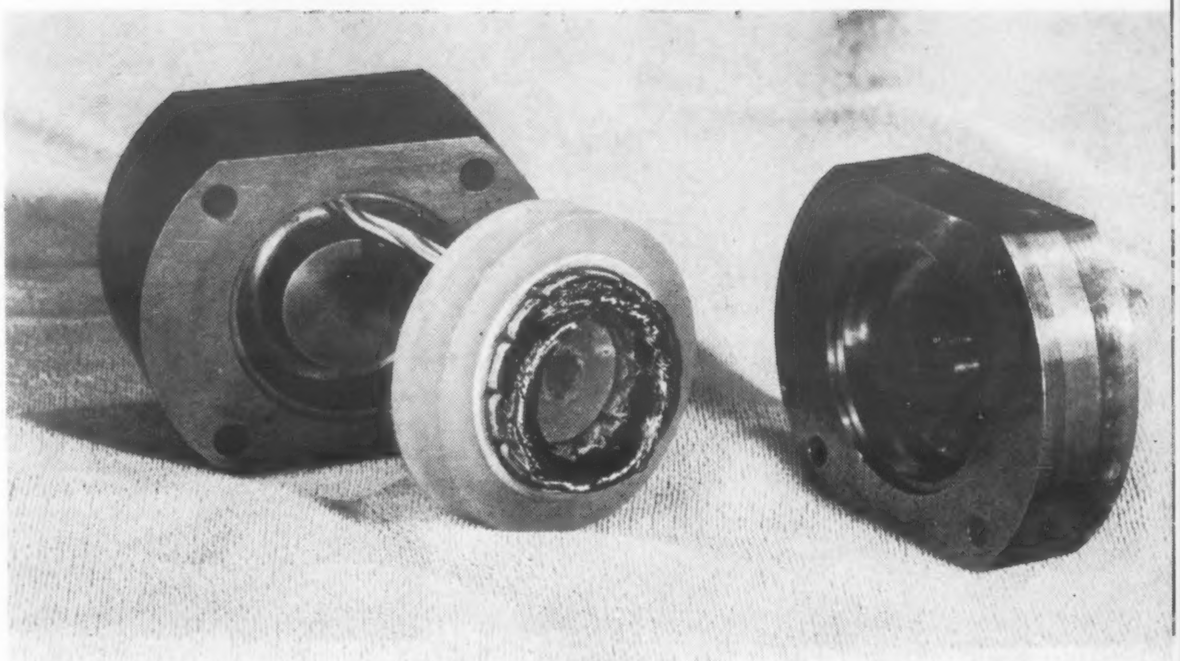


Fig 3—*Inner and outer seals on stator keep resin away from critical areas and prevent air leakage during vacuum casting.*

The laboratory equipment and setup used for the vacuum casting process is shown in Fig 5. This equipment was designed so that the resin could be brought in under vacuum to fill a well in top of the mold. When the well is filled, the resin is forced into the evacuated cavity by releasing the vacuum.

Curing stresses in the production setup are reduced to a minimum by heating the casting from the bottom by means of a hot plate at the bottom of the mold. In addition, the hot plate takes up less space and provides a faster cure than the oven used in the laboratory process. The resin reservoir at the top of the mold is carefully designed to prevent waste and to hold just the right amount of liquid resin to compensate for shrinkage due to gelation.

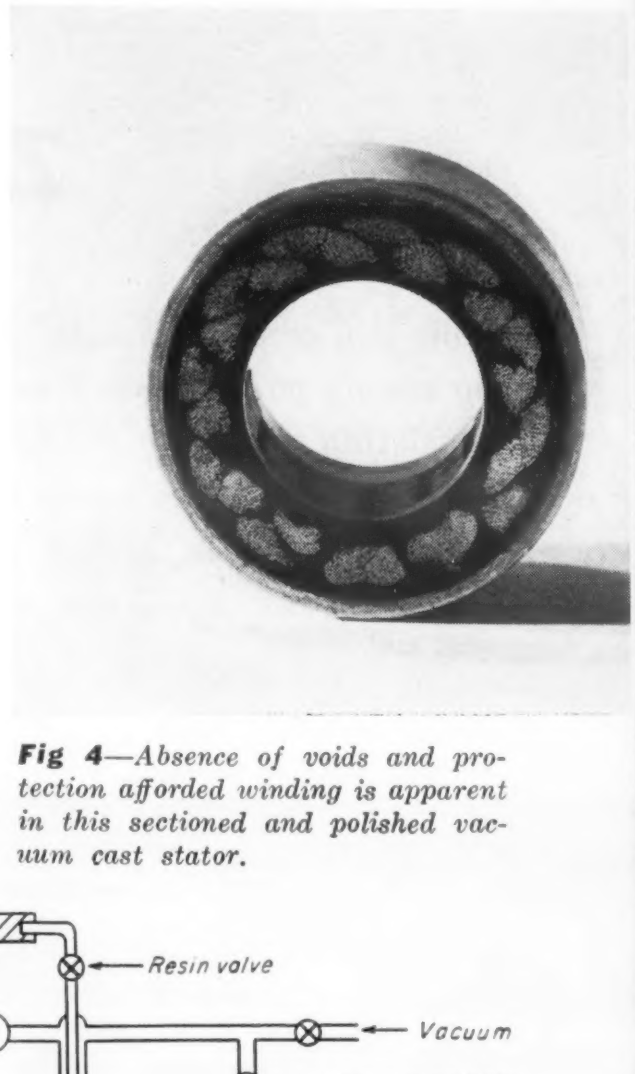


Fig 4—*Absence of voids and protection afforded winding is apparent in this sectioned and polished vacuum cast stator.*

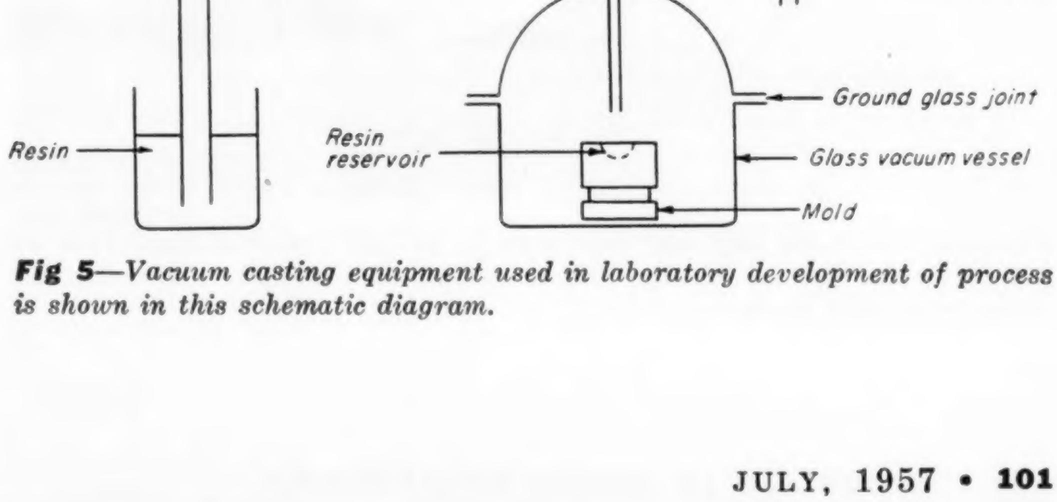
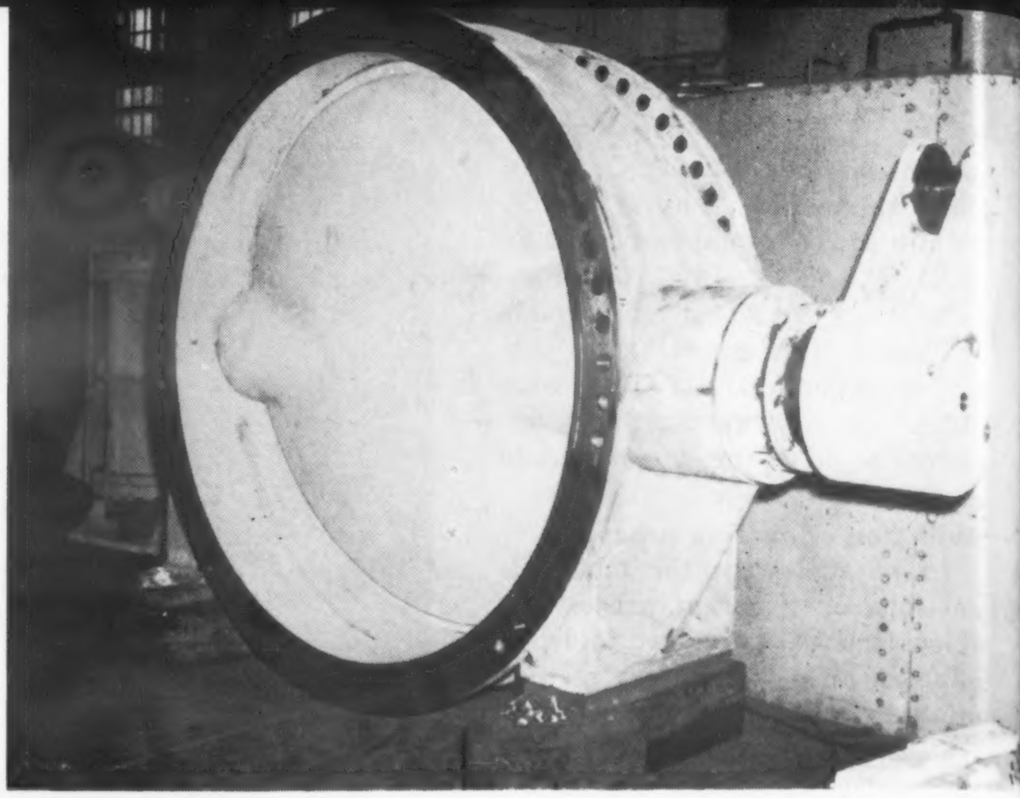


Fig 5—*Vacuum casting equipment used in laboratory development of process is shown in this schematic diagram.*

Sealube Co.

Castings *are protected by organic zinc-rich paint during outdoor exposure.*



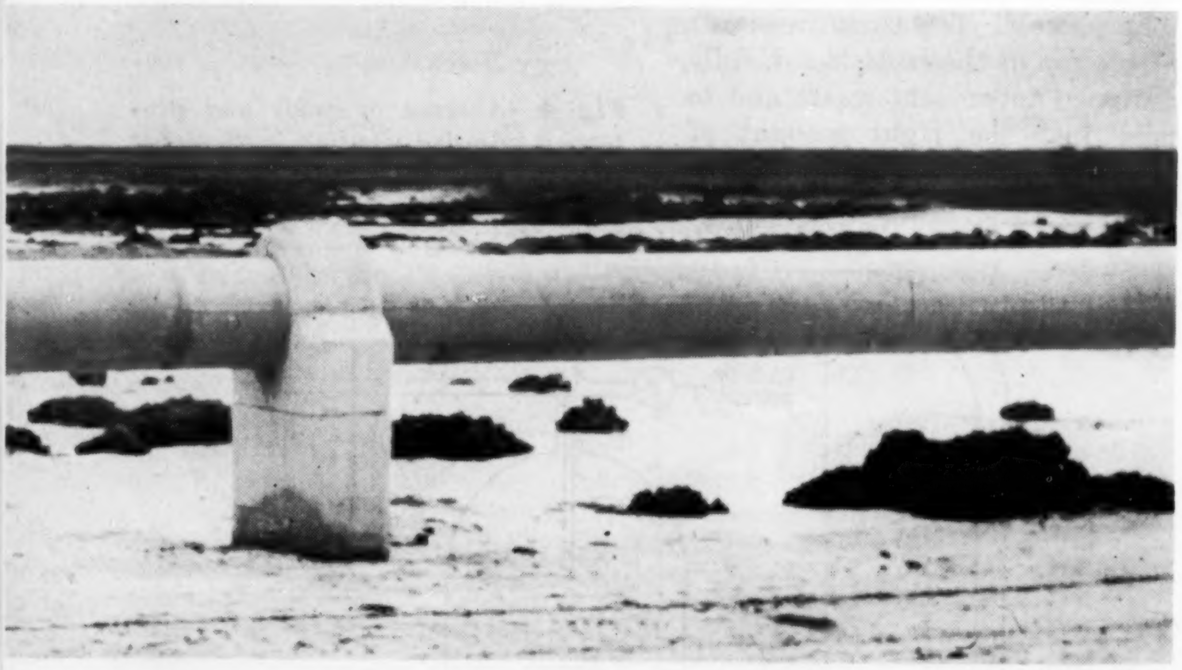
Debevoise Co.

Butterfly valve *typifies parts subject to continuous water immersion that can be protected by zinc-rich paints.*

Zinc-Rich Paints Protect

Now you can "galvanize" ferrous surfaces by simply painting on a suspension consisting mainly of metallic zinc.

by **Robert J. Fabian,** *Associate Editor, Materials in Design Engineering*



Amercoat Corp.

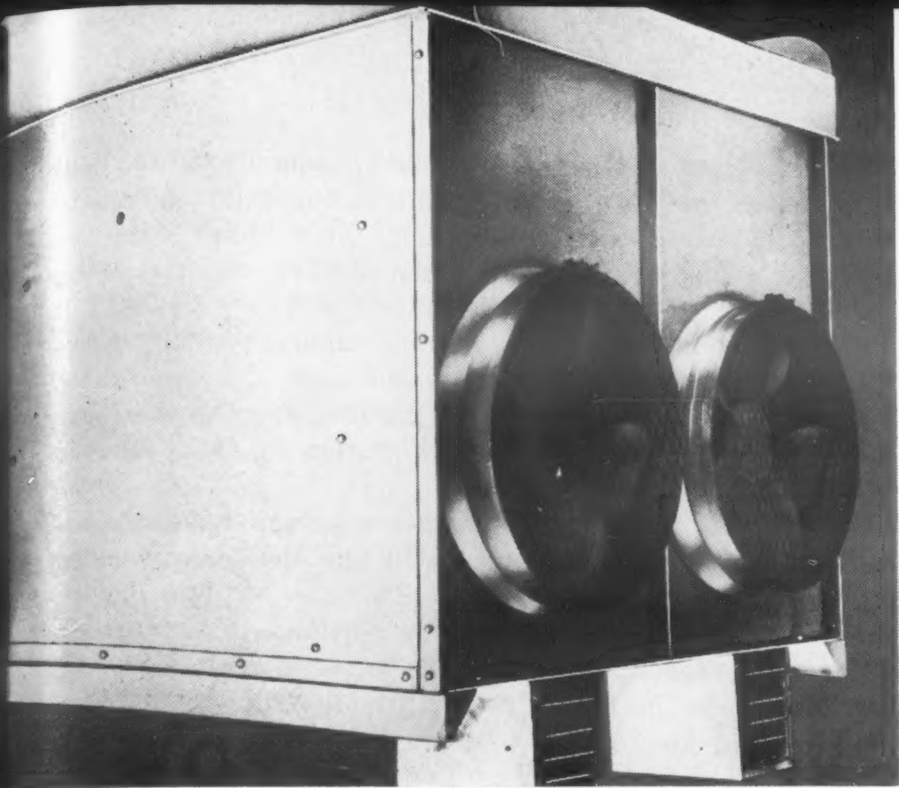
Pipeline *223 miles long has been kept in perfect condition since 1942 by inorganic zinc silicate coating, despite continuous exposure to sea air, salt water spray and sandstorms.*

■ Paint films containing 80 to 95% by weight of concentrated zinc are now being used to protect a wide variety of ferrous parts against corrosion and abrasion. These coatings—not to be confused with conventional zinc-pigmented paints—consist almost entirely of electrically conductive zinc particles. In many applications the coatings have proved to be as effective as galvanized and electroplated coatings in combating corrosion.

In general, zinc-rich coatings can be classified as organic or inorganic, depending on the type of vehicle or binder used. The inorganic coatings are formulated by mixing sodium silicate and finely divided zinc powder, which react to form zinc silicate. The organic coatings are formulated by mixing zinc powder with one of a number of organic vehicles such as polystyrene, chlorinated rubber, polyvinyl acetate, acrylic, epoxy, alkyd or phenolic.

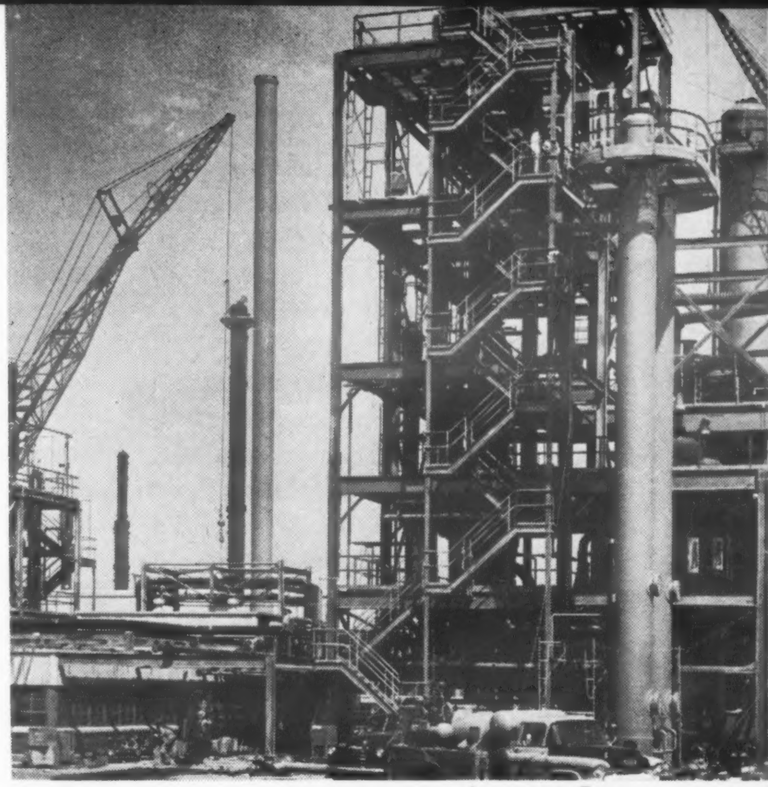
Properties

Weathering resistance — The outstanding property of zinc-rich



Industrial Metal Protectives, Inc.

Cooling tower *surfaces exposed to corrosive environments are protected by inorganic zinc silicate coating.*



Amercoat Corp.

Pipes, structural steel *and tanks of this chemical plant are coated with inorganic zinc-rich primer and vinyl topcoat for maximum abrasion and corrosion resistance.*

Iron and Steel Parts

coatings is their resistance to weathering. In many applications these coatings have proved to be as effective as galvanized or electroplated coatings. Inorganic zinc silicate coatings were originally developed in Australia, and one of the first large scale applications made there was to the exterior of a 223-mile above-ground pipeline. The coating was applied 14 years ago and the pipeline has not needed any repainting since, despite continuous exposure to sea air, salt and fresh water, dust storms and severe extremes of humidity and temperature. Furthermore, there has been no evidence of ultraviolet fading, chalking or other type of failure.

The inorganic coatings have also demonstrated excellent durability during artificial weathering tests. Coated steel panels, exposed alternately in a salt spray chamber and in a weatherometer, have shown no signs of corrosion after over 11,000 hr of testing. Similarly, coatings utilizing organic vehicles have been given salt spray tests for 8000 hr, with no evidence of failure until after 3000 hr.

Chemical and water resistance—In general, zinc-rich coatings can be used in contact with salt and fresh water. The inorganic coatings are especially noted for their resistance to petroleum, aromatic and chlorinated (as long as no moisture is present) hydrocarbons, vegetable and animal oils, ketones and esters, and alcohols. Despite their resistance to salt and fresh water at normal outdoor temperatures, zinc-rich coatings are not generally recommended for immersion in water above 140 F. At this temperature it is believed that the sacrificial action of the zinc reverses itself; however, this point is debatable, and some organic formulations have been claimed to protect metals up to 212 F.

Acid and alkali resistance—Because of their high zinc content, zinc-rich coatings should not be exposed to acids or alkalis. In general, it is safe to use the coatings in a pH range of 6 to 12. In applications outside of this range some sort of barrier coating is necessary to protect the zinc from attack.

Temperature resistance — All zinc-rich coatings can be used at temperatures as low as -65 F with excellent results. Coatings utilizing organic binders can generally be used to about 450 F before the resin burns off. Above this temperature, it is claimed that the zinc still adheres firmly to the basis metal and affords a fair measure of protection.

The inorganic coatings have a somewhat higher temperature range and are capable of operating continuously at 500 F, and for brief periods at 700 to 1000 F, without detriment to the coating or binder. The coatings have proved quite effective on baffle plates used in jet exhaust sound deadening chambers and on automobile exhaust pipes.

Formulation and application

Inorganic coatings — All inorganic zinc-rich formulations are two-part systems that are prepared shortly before application. Roughly 22 lb of zinc dust and

$\frac{2}{3}$ gal of vehicle are required to produce 1 gal of mixed coating. To allow entrapped air to escape, the formulation must be allowed to stand 30 min before use.

To obtain good adhesion it is usually necessary to sandblast all surfaces free of mill scale, rust, grease or other foreign matter. In some special applications vapor degreasing may be sufficient. To function properly the paint should be applied directly to the basis metal. Spray application is generally preferred; however, the coatings may also be applied by brush, dip or flow coat methods. Dipping is preferred for coating small parts and interior surfaces, but some form of agitation must be used to keep the zinc particles in suspension.

Inorganic zinc-rich coatings must be cured before being placed in service. Curing is accomplished either by baking or by application of a chemical curing solution. Prior to baking, the coating must be allowed to air dry for about 15 to 30 min until the coating becomes light gray in color. The baking cycle usually consists of exposure for 1 hr at 350 F.

Chemical curing, of course, is particularly advantageous on large outdoor structures that cannot conveniently be baked. Normal coverage of the curing solution is about 300 to 400 sq ft per gal. The surface should be free of moisture for at least 24 hr.

One coat of the inorganic type formulation in a thickness of $2\frac{1}{2}$ mils is usually sufficient for most applications. Coverage is about 350 sq ft per gal. Cost of the coating is roughly 5¢ per sq ft, plus slightly over 1¢ per sq ft for the curing solution, if needed.

Organic coatings—These coatings are formulated and applied in much the same way as the inorganic coatings. There are, however, some important differences between the two types of coatings.

The surface preparation required for organic coatings is not as exacting as that required for inorganic coatings. Sandblasting may not be required and wire brushing and chemical cleaning is often sufficient to remove light rust, scale and grease.

Most organic formulations are two-part systems that are mixed before application. In contrast with the inorganics, two coats of the organic formulations are usually required to achieve adequate protection. This factor does not have much effect on material costs, however, since two coats of an organic coating are roughly equivalent to one coat of an inorganic coating in coverage. Cost of the two-coat system is about 4¢ per sq ft.

Organic coatings have an advantage in that they can be cured by air drying. Coatings dry to the touch in from 5 to 45 min, dry to handle in from $1\frac{1}{2}$ to 4 hr, and dry to a hard finish in about 24 hr. Complete curing for maximum chemical and solvent resistance may take several days; however, the coatings can be completely cured by baking for about 10 min at 300 F.

Uses

Zinc-rich coatings are ideally suited for the protection of all ferrous surfaces exposed to corrosive atmospheres or water. The coatings have been used effectively on equipment exposed to continuous or intermittent wetting such as: air conditioning ducts, refrigeration equipment, water tanks, penstocks, recirculating water pipes and dam gates. The coatings are also widely used for equipment maintenance and have proved quite valuable in touching up galvanized surfaces that have been welded or damaged.

In the electrical industry the coatings are being used to protect such equipment as: insulator domes, capacitor boxes, transformer housings and transmission towers. In the petroleum industry the coatings have been used on: pipelines, tanks, offshore structures and caissons, drilling rigs, cooling towers, steel structures, etc. Similar applications have been made in chemical process equipment and plants.

Acknowledgment

The author would like to express his appreciation for the assistance of personnel and literature from the following companies in preparing this article:

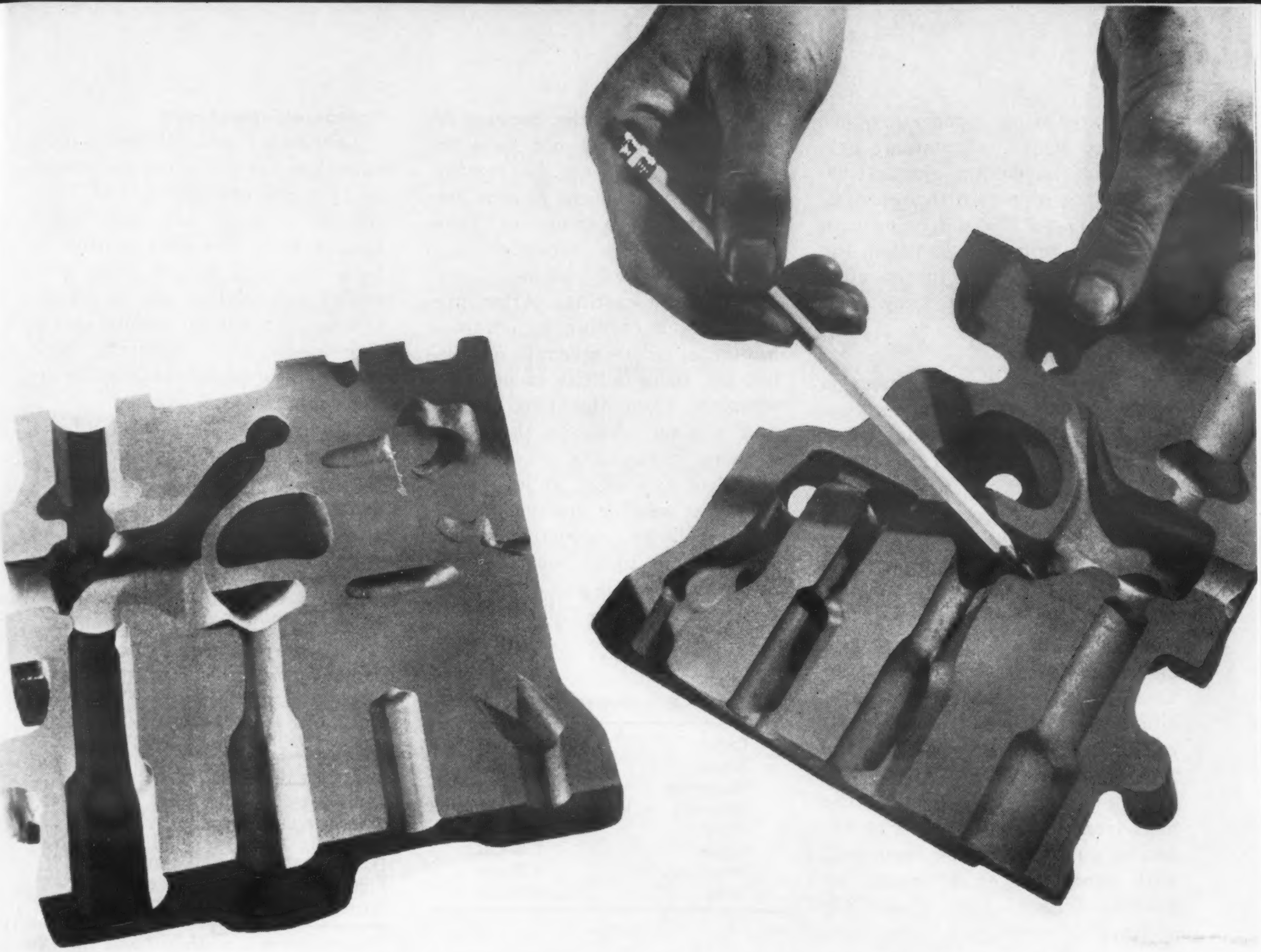
Amercoat Corp.
Debevoise Co.
Industrial Metal Protectives, Inc.
New Jersey Zinc Co.
Pigment & Chemical Co., Ltd.
Sealube Co.
Steelcote Mfg. Co.
Subox, Inc.

How the Coating Protects

The protective action of zinc-rich paints stems from the sacrificial action of zinc in the presence of an electrolyte (water). Because zinc is more electropositive, it becomes the anode and the ferrous surface becomes the cathode during corrosive action. Corrosion occurs at the anode, where metal in the form of zinc ions passes into solution. Hydroxyl ions, formed during the dissociation of water, collect at the ferrous surface.

During the early stages of corrosion, protection is provided by the sacrifice of zinc for the ferrous metal. As weathering continues, however, the formation of zinc hydroxide and other basic zinc compounds on the ferrous surface tends to slow down the self-sacrificing action of the zinc and prolongs the life of the surface.

These zinc compounds play another important part in the protective action of the coating. If a break should occur, the exposed metal will still remain protected long after the coating has stopped being conductive. This protection is due to the deposition of basic zinc compounds on the basis metal at the break. These compounds react with any iron compounds that form and convert them into a clinging type of rust that has no tendency to spread or creep under the paint film.



Flow divider and fuel selector *casting (sectioned to show design of internal passages). Cast 17-4 PH was selected for this part to meet requirements of high pressure and high temperature operation.*

17-4 PH Castings

Strong and Corrosion Resistant

Four years' experience makes it possible to predict properties of this precipitation hardenable stainless steel in cast form. Availability of such data should broaden applications.

by David C. Ekey, *Technical Director,* **and Erroll V. Black,** *Chief Quality Control Engineer, Lebanon Steel Foundry*

■ A combination of high strength, corrosion resistance and simple heat treatment has made Armco 17-4 PH a valuable material for aircraft and other specialized applications. The cast version of this steel, designated L17 by Lebanon, has been in production for about four years, during which time castings varying in size from a few ounces to 450 lb have been produced.

Among production items at Lebanon are a flow divider and fuel selector for a jet engine, an engine removal track, high speed impellers, and valve parts for corrosion resisting applications. The alloy has been used also to replace 18% chromium steel in marine, food and chemical equipment.

Composition of the cast alloy is about 16 chromium, 4 nickel and 2.5% copper (see Table 1). Cor-

rosion resisting properties are imparted by the chromium; precipitation hardening characteristics by the copper. Although castings of 17-4 PH could be used in a solution annealed condition, the advantages inherent in the alloy can only be developed by heat treatment.

Heat treatment

A two-stage heat treatment is required to develop optimum properties in 17-4 PH castings. The castings are heated to the range 1900 to 2100 F for periods that depend on the section thickness and air cooled to room temperature. After this treatment the castings are in the softest condition that can be obtained.

For maximum hardness and strength the high temperature treatment is followed by a precipitation hardening treatment consisting of heating at 875 F for 1 hr and air cooling. Properties can be altered by changing the heat treating conditions. For example, ductility can be improved, with some loss in strength, by heating 3 hr at 1050 F and air cooling.

Mechanical properties

The mechanical properties of cast 17-4 PH depend on the precipitation hardening treatment used. Table 2 shows the minimum properties obtained by using two different hardening treatments. It should be emphasized that these are minimum properties and that most heats will have properties considerably higher. Expected values are given in a series of graphs based on statistical analysis of many production heats.

The effect of section thickness on properties is important in designing with castings, because the cast test bar may not have the same properties as the casting, particularly if there is considerable difference in thickness. Table 3 compares the properties of a cast test bar with those of sections of the casting. After precipitation hardening to obtain a minimum tensile strength of 130,000 psi, there is little variation in strength from the 1-in. to the 4-in. section, although there is a decrease in ductility.

Use of this alloy in jet engine parts is possible because it retains a large proportion of its strength up to at least 800 F. Short time tensile and creep properties are given in Table 4.

TABLE 1—COMPOSITION, %

Carbon	0.07 max
Silicon	1.00 max
Manganese	1.00 max
Chromium	15.25-17.25
Nickel	3.00-5.00
Copper	2.30-3.00
Phosphorus	0.04 max
Sulfur	0.04 max

TABLE 2—MECHANICAL PROPERTIES

Property	Hardening Temp, F[a]	
	875	1050
Tensile Strength, 1000 psi	170 min	130 min
Yield Strength (0.2%), 1000 psi	140 min	100 min
Elongation, %	6 min	12 min
Reduction of Area, %	15 min	30 min
Brinell Hardness	360-420	269-350
Endurance Limit (10^7 cycles), 1000 psi[b]	—	85

[a]Solution annealed 1 hr at 1900 F, air cooled to room temperature, precipitation hardened 1 hr. Minimum values based on statistical analysis of production heats.
[b]Source: Armco Steel Corp.

Corrosion resistance

Laboratory and field tests indicate that the corrosion resistance of 17-4 PH exceeds that of 12% chromium steel and approaches that of 18-8. The alloy is particularly resistant to salt water corrosion and pitting, and is recommended for use in mildly corrosive applications requiring high strength combined with antigalling properties.

Condition of the metal affects the corrosion rate, however, and the proper heat treatment must be selected if corrosive conditions are to be met in service. The standard test for evaluating the

TABLE 3—EFFECT OF SECTION THICKNESS

Property	Section Thickness, in.[a b]		
	1	1½	4
Tensile Strength, 1000 psi	148	145	144
Yield Strength (0.2%), 1000 psi	131	131	128
Elongation, %	19.0	18.5	13.5
Reduction of Area, %	53.3	52.0	36.5
Brinell Hardness	302	302	302

[a]Heat treated to a minimum tensile strength of 130,000 psi.
[b]1-in. section from standard test bar cast with impeller; 1½ and 4-in. sections from impeller.

TABLE 4—HIGH TEMPERATURE PROPERTIES

Temp	700 F	800 F
Tensile Strength, 1000 psi	158	157.5
Yield Strength (0.2%), 1000 psi	138	137.5
Stress Rupture Str, 1000 psi		
100 hr	134	130
1000 hr	130	89
Creep Strength, 1000 psi		
0.1% in 1000 hr	120	50
0.01% in 1000 hr	80	—

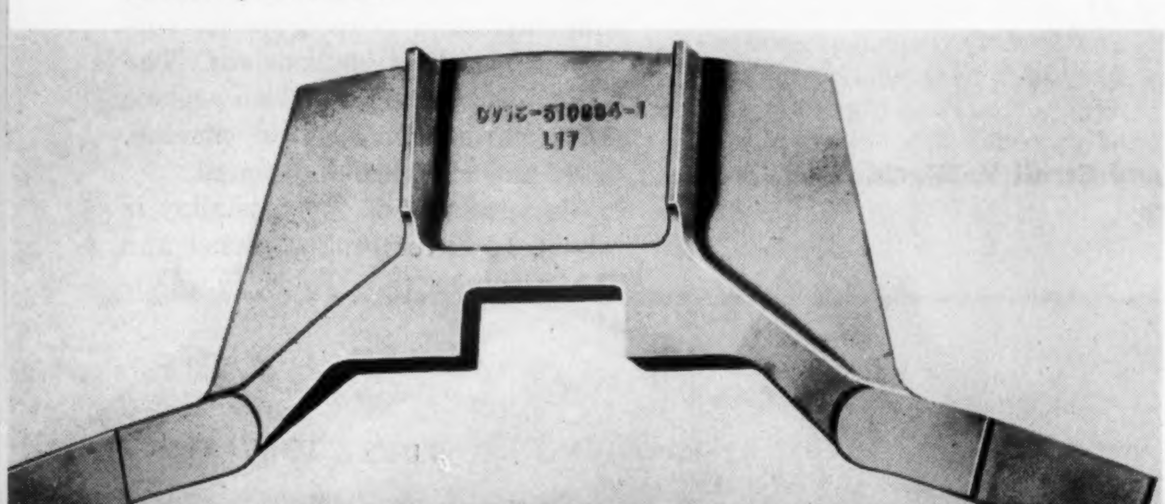
Source: Armco Steel Corp.

TABLE 5—EFFECT OF HEAT TREATMENT ON NITRIC ACID CORROSION

Heat Treatment	Corrosion Rate, in./month[a]
2050 F, 2 hr[b]	0.00485
2050 F, 2 hr[b]; 875 F, 1 hr[b]	0.00394
2050 F, 2 hr[b]; 1025 F, 3 hr[b]	0.1809

[a]Corrosion by boiling 65% nitric acid; avg of five 48-hr runs.
[b]Air cooled.

Support fitting *for jet engine removal track of the Chance Vought F8U-1 is cast of 17-4 PH.*



relative resistance of stainless steels is the boiling 65% nitric acid test. In this test a series of runs, usually of 48-hr duration, is made and the average corrosion rate is determined. Table 5 shows the corrosion rates of 17-4 PH after different heat treatments. The best resistance is obtained by solution annealing, followed by precipitation hardening at 875 F. Precipitation hardening at 1025 F greatly decreases the resistance to nitric acid attack.

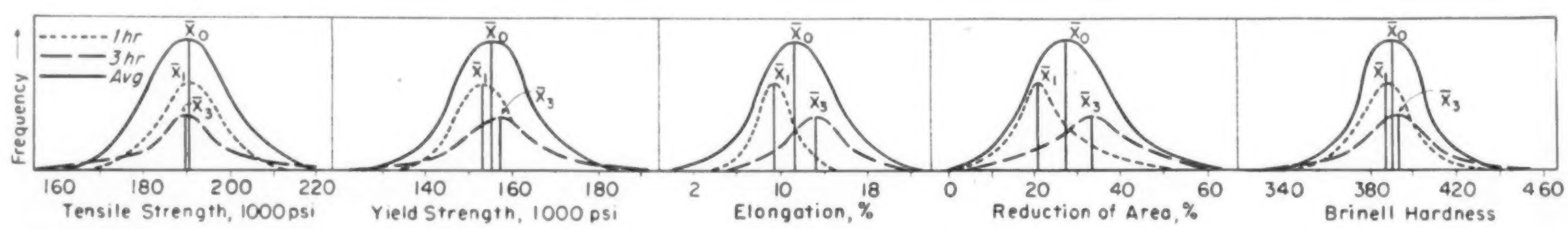
Production

Like most high strength alloys, 17-4 PH presents some casting difficulties. Although the alloy has good fluidity and can be cast without internal porosity and internal cracking, it resembles type 410 steel in its tendency toward surface stress cracking during cooling after solidification. Proper design that eliminates abrupt changes in section, sharp internal corners and heavy X or T sections will permit the production of castings free from surface cracking. Complexity of the casting largely determines the difficulties that will be experienced in producing the part and the resulting cost to the buyer.

Machining — Solution annealed castings can be machined by the procedures used in machining type 410 stainless at a Brinell hardness of 280-320. After precipitation hardening machining is more difficult and rates should be reduced about 40%. Because the hardening temperature is low, a casting can be machined to size in the solution annealed condition, making no allowance for scaling or distortion during hardening.

In the as-cast condition, powder or arc burning can be used to remove risers or to perform other cutting operations. In the precipitation hardened condition, machining or abrasive wheel cutting should be used to prevent stress cracking.

Welding—Cast 17-4 PH can be welded by all of the methods used with the austenitic stainless steels. It has excellent welding characteristics and is not subject to intergranular corrosive attack resulting from the welding operation. Thus, preheating and annealing after welding are not required. Filler metal of 17-4 PH should be used to obtain mechanical properties and corrosion resistance comparable with that of the base metal.



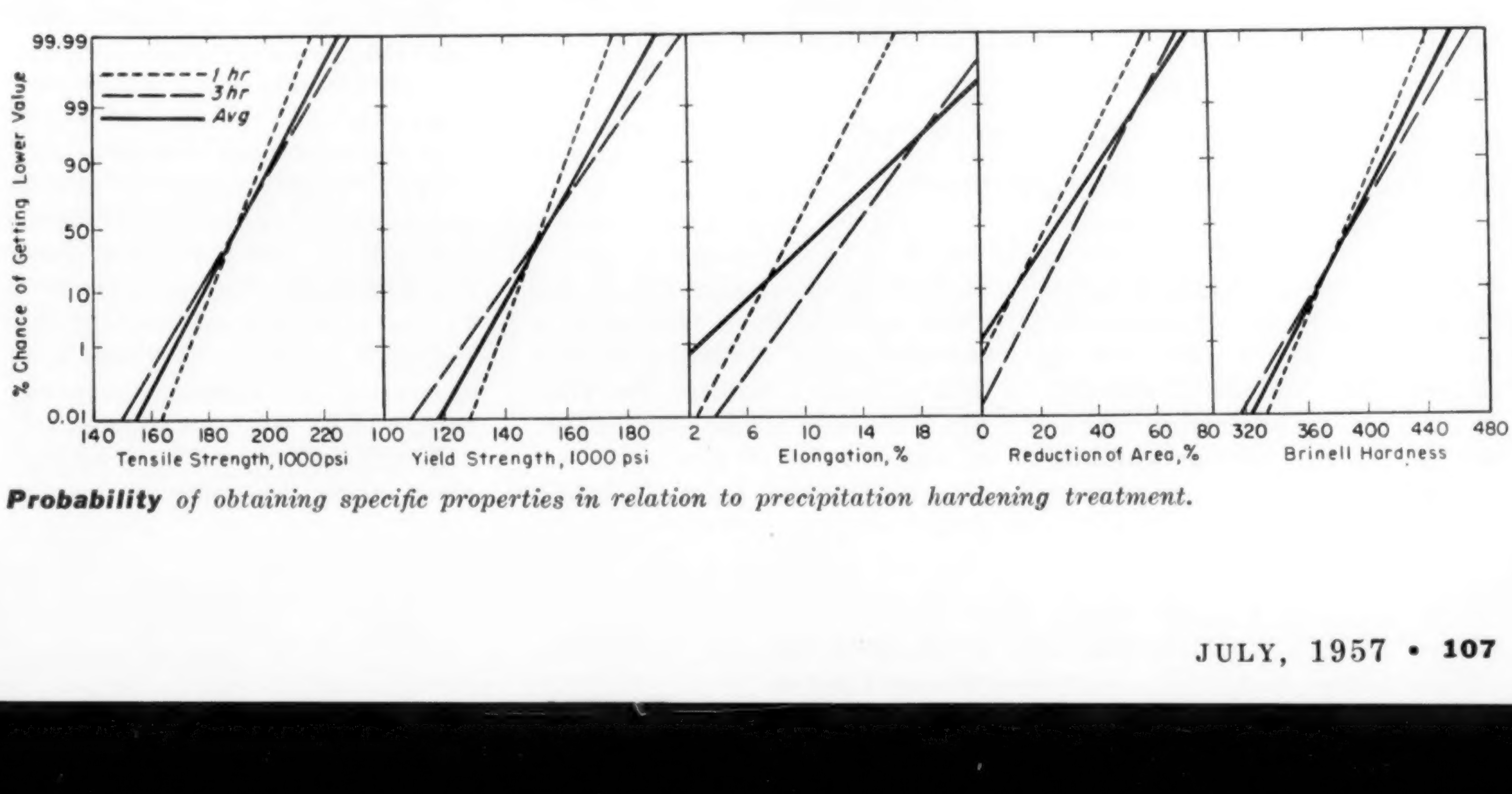
Frequency distribution *of properties with relation to precipitation hardening treatment.*

Expected Properties of 17-4 PH Castings

Statistical analysis of many heats of cast 17-4 PH shows that design based on the minimum values given in Table 2 can be used with assurance that the properties of the casting will always exceed these values.

The effect of heat treatment on the frequency distribution of various mechanical properties is shown in a series of graphs for precipitation hardening treatments at 875 F and periods of 1 and 3 hr. These graphs show, for example, that the 1-hr treatment time produces higher average strengths than the 3-hr time, but the 3-hr treatment produces higher average ductilities than the 1-hr treatment. Selection of treatment time can be based on whichever property is the more important.

A second series of graphs for the same properties shows the probability that any sample, after heat treatment at 875 F for 1 hr or 3 hr, will fall below a given value. For example, assuming that a tensile strength of 180,000 psi is desired, the tensile strength probability graph shows that 92% of the castings will reach this value after a 1-hr treatment, but that a 3-hr treatment will reduce the probability to 81%. Therefore a 1-hr treatment should be selected.



Probability *of obtaining specific properties in relation to precipitation hardening treatment.*

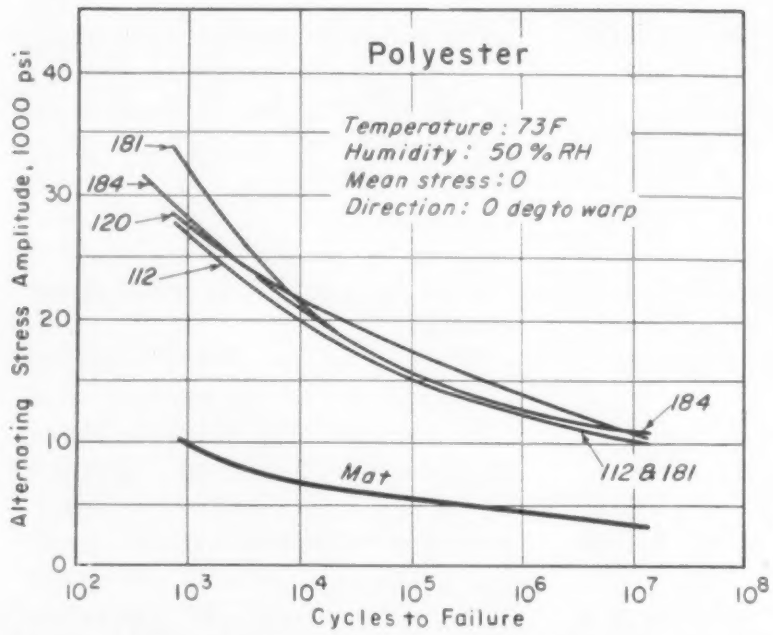


Fig 1—*Effect of type of glass reinforcement on unnotched polyester laminate.*

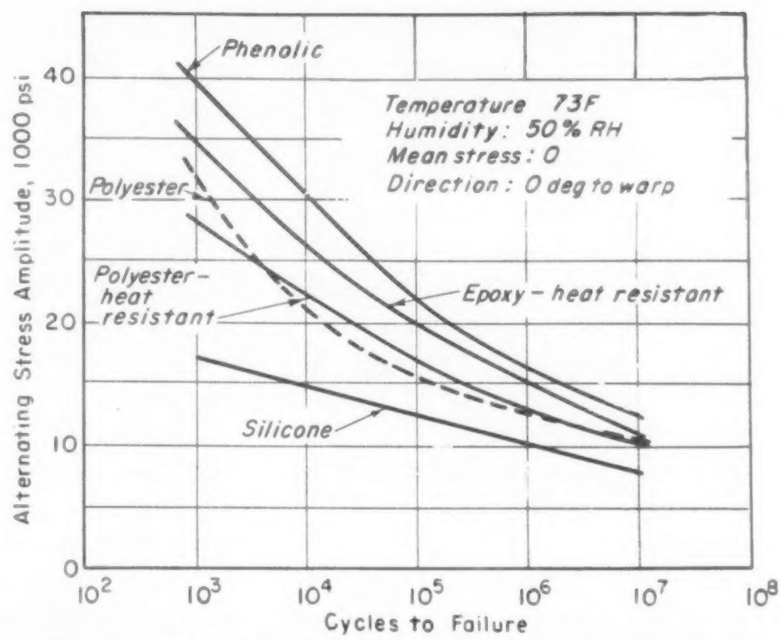


Fig 2—*Effect of type of heat resistant resin on unnotched laminates reinforced with 181 glass fabric.*

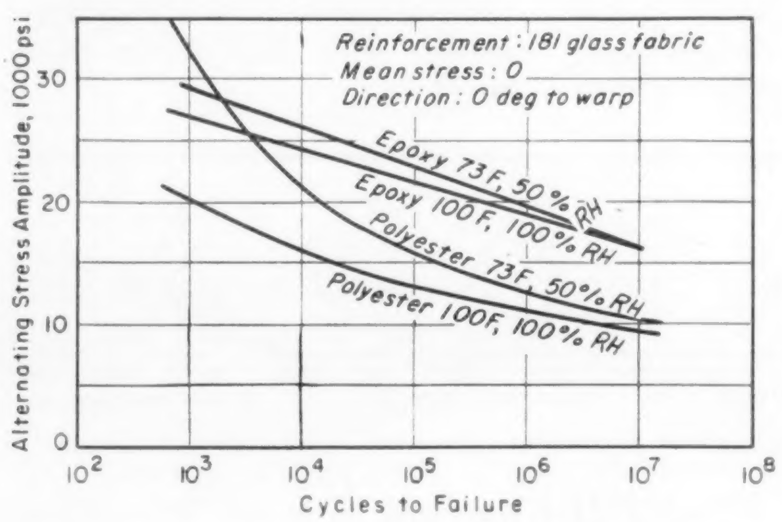


Fig 3—*Effect of moisture on unnotched polyester and epoxy-glass laminates.*

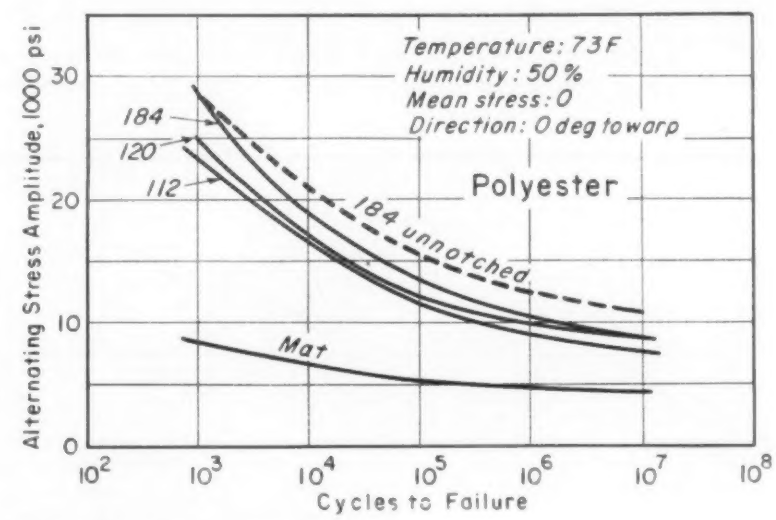


Fig 4—*Effect of stress concentration on notched polyester-glass laminates.*

These curves give Fatigue Properties of Reinforced Plastics

Data on what happens to glass-reinforced laminates subjected to repeated stresses have been slow in developing. Here are the results of one of the most extensive studies yet made.

■ The growing emphasis on structural applications of reinforced plastics has put a premium on fatigue data. Where alternating stresses are to be encountered in service the designer or engineer in order to design effectively, must know the magnitude of the effect these stresses will have on the strength of the material after long periods of service. For plastics these data are limited because of the newness of plastics as engineering materials and the length of time necessary to develop adequate fatigue information.

The curves and data given here are taken from a technical report of the Wright Air Development Center on work done under USAF contract at Forest Products Laboratory. The data show the effects of five design variables on fatigue strength of glass-reinforced plastics laminates. The variables are: 1) type of glass reinforcement and resin, 2) moisture, 3) stress concentration, 4) elevated temperature, and 5) mean stress level.

The designer should be cautious about using these curves directly

for design purposes. Reinforced plastics are extremely complex materials involving many variables. The data given here represent values obtained on the specific materials described in an accompanying box and cured under specific conditions. Fatigue characteristics may not be the same for some production laminates prepared in slightly different ways. Also, since these curves are based on the number of cycles to complete fracture at designated alternating stress amplitudes, no safety factor has been included.

Reinforcement and resin

Fig 1 shows the effect of the type of glass reinforcement on fatigue strength of unnotched polyester laminates. Laminates reinforced with different weaves of glass fabric have essentially the same fatigue strength over the 10,000 cycle level. Mat-reinforced laminates have considerably lower fatigue strength. Most fatigue strength values for glass-reinforced plastics at 10 million cycles are about 20 to 25% of static tensile strength.

Effect of direction of loading on fatigue strength is shown in Fig 5 which compares fatigue strength of polyester laminates loaded at 45 deg to warp with that of laminates loaded parallel (0 deg) to warp, at temperatures of 73, 300 and 500 F. Static tensile strength at 45 deg to warp is usually lower than that at 0 deg to warp and consequently fatigue strength is also lower.

At room temperature, laminates at 45 deg to warp reach an endurance limit of 6500 psi at about 40,000 cycles. These values agree with previously obtained data. Laminates loaded at 0 deg to warp do not show an endurance limit at room temperature, even at 10 million cycles. At elevated temperatures the S-N curves continue downward to such a degree that it is uncertain whether or not an endurance limit is reached at 10 million cycles.

Fig 2 shows effect of type of resin on fatigue. At 10 million cycles phenolic laminates show the highest fatigue strength, followed by heat resistant epoxy, polyester and silicone.

Moisture

Although the moisture absorbed by glass-reinforced laminates is only on the order of 0.5 to 2%, it causes reductions in both static short time strength and in fatigue strength. For example, the short time tensile strength of a standard polyester laminate is reduced from 46,000 to 42,300 psi by moisture, and fatigue strength at 1000 cycles is reduced from 10,400 to 9400 psi (see Fig 3). As number of cycles is increased, the effect of moisture in reducing fatigue strength lessens so that fatigue strength of standard polyester resin laminates at 10 million cycles after moisture conditioning is reduced by only 2% of their static tensile strength.

The effect of moisture on fatigue strength of epoxy laminates seems to be negligible.

Stress concentration

Notching reduces the fatigue strength of reinforced plastics in almost every case. Fig 4 shows the magnitude of this effect on stand-

Based on WADC Technical Report 55-389, "Fatigue Properties of Various Glass-Fiber-Reinforced Plastic Laminates," by K. H. Boller, Forest Products Laboratory, May '56.

How the Curves Were Obtained

Materials

All specimens were flat, glass-reinforced panels approximately ¼ in. thick, made or procured by Forest Products Laboratory to materials specifications supplied by Wright Air Development Center.

Of the 10 laminates studied, four were made with heat resistant resins: 1) TAC-modified polyester (PDL-7-669, 2) epoxy (Epon X12100), 3) phenolic (BV 17085), and 4) silicone (DC 2106). All of these laminates were reinforced with 181 glass fabric with Volan A finish, except the silicone laminates, which were made with heat-cleaned 181 glass fabric. The other six laminates were standard materials: an epoxy (Epon 828 CL and five polyesters (Paraplex P 43). The standard epoxy laminate was reinforced with 181 cloth and the polyester laminates were reinforced with 181, 112, 120 and 184 cloth and a 1½ oz mat. All of the woven fabrics had Volan A finish and were parallel laminated.

Notched specimens were the same size and shape as the unnotched specimens. The notch was a hole of ⅛-in. dia at the center of the specimen. Data from previous work indicate that the notch and the 4-in. radius used to reduce the width of the specimen caused a reduction in average stress of 20 to 28% in tension and an increase in average stress of 6 to 20% in compression.

Test procedure

Ten specimens for fatigue tests and five specimens for static tests of ultimate tensile strength were cut from each material, making a total of 15 basic matched specimens for each S-N curve. After static ultimate tensile strengths had been determined, alternating stress amplitudes were assigned to a series of fatigue specimens of that material. The highest alternating stress assigned was about 70% of the static tensile strength, and the percentage was decreased on subsequent specimens until a specimen endured 10 million cycles. Curves were then plotted from cycles-to-rupture at the various alternating stress amplitudes.

All fatigue specimens were axially loaded by fatigue machines. For high temperature tests, the specimens were enclosed in ovens. Tension and compression loads were applied alternately by an eccentric operating at 900 rpm. Heat generated in the neck section of specimens was removed by a 12-in. fan continuously blowing air past the specimen.

ard polyester laminates reinforced with various types of glass cloth and mat. The effect of notch on fatigue strength is clearly shown when the curves of Fig 4 are compared with those of Fig 1. For standard polyester laminates, reductions in fatigue strength caused by notching are approximately the same at various cycle levels up to 10 million cycles. This is indicated by the parallelism of corresponding S-N curves in Fig 1 and Fig 4. Effect of notch on heat resistant epoxy, phenolic and silicone laminates is shown in Fig 6, 7 and 8.

Average fatigue strength of notched laminates at room temperature after 10 million cycles at zero mean stress is about 23% of room temperature ultimate tensile strength, as compared with about 27.5% for unnotched laminates. This 4.5% reduction is reflected in the difference between notched and unnotched S-N curves.

Effect of notching on fatigue strength at 10 million cycles at elevated temperatures, particularly 500 F, is generally smaller than at room temperature. Fig 6, 7 and 8 compare the fatigue strengths of heat resistant epoxy, phenolic and silicone laminates at room temperature, at 300 F and at 500 F. The curves for phenolic and silicone laminates show most clearly the decreasing effect of notch on fatigue strength as temperatures increase. At elevated temperatures, failure of specimens is commonly in compression. Since the notch tends to have a lesser effect on failure in compression than on failure in tension fatigue data at elevated temperatures should probably not be used to determine notch sensitivity of a material.

Elevated temperature

Exposure to elevated temperatures reduces fatigue strength. Fatigue data for heat resistant polyester, epoxy, phenolic and silicone laminates are shown in Fig 5, 6, 7 and 8 at room temperature, at 300 F and at 500 F. The degree to which fatigue strength suffers is dependent on the type of resin and its ability to retain strength after increasing periods of high temperature exposure.

A word of caution should be given regarding these high temperature fatigue data. As is pointed out in an accompanying box, all tests were carried out at a frequency of 900 cycles per min. Since the frequency used determines the length of exposure of the specimens to elevated tem-

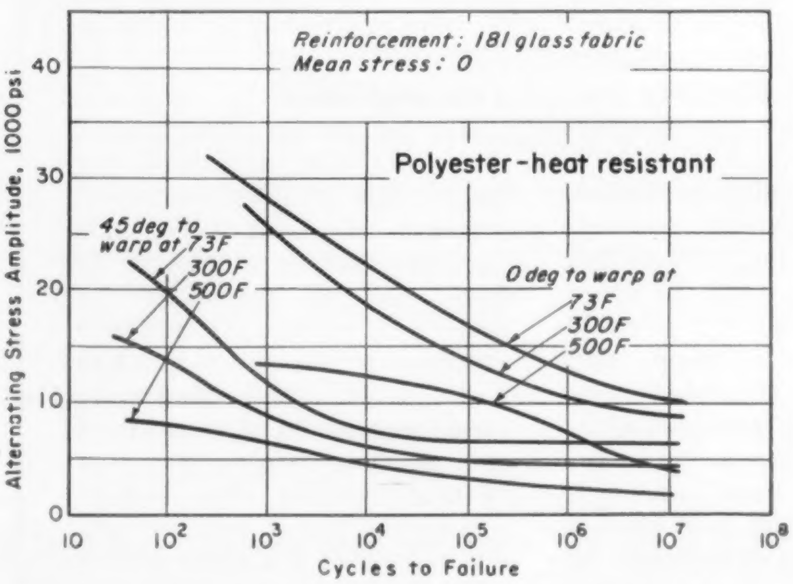


Fig 5—*Effect of temperature and direction of loading on unnotched heat resistant polyester-glass laminates.*

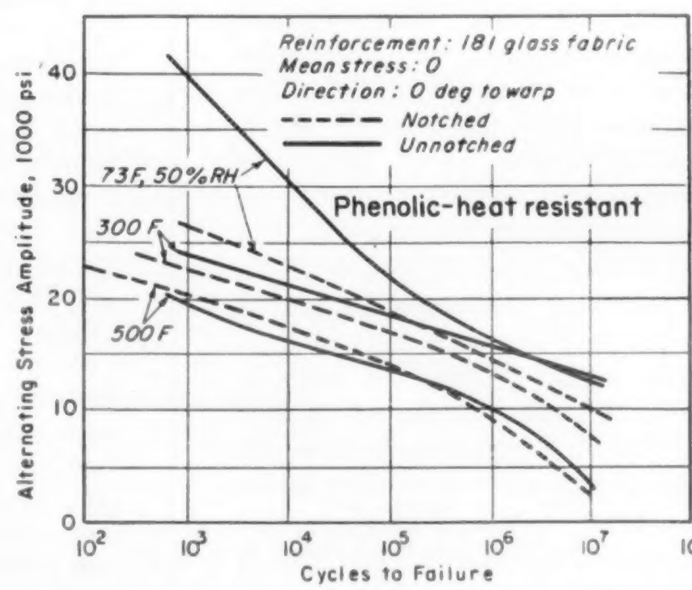


Fig 7—*Effect of heat on unnotched and notched heat resistant phenolic-glass laminate.*

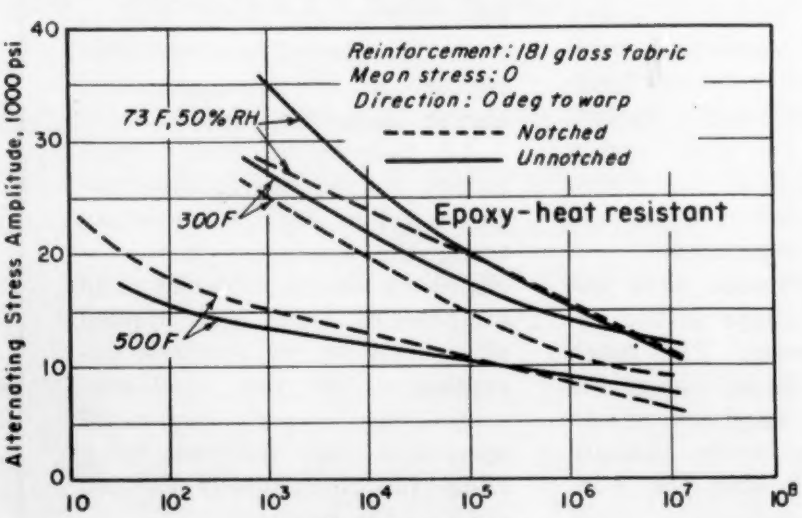


Fig 6—*Effect of heat on unnotched and notched heat resistant epoxy-glass laminate.*

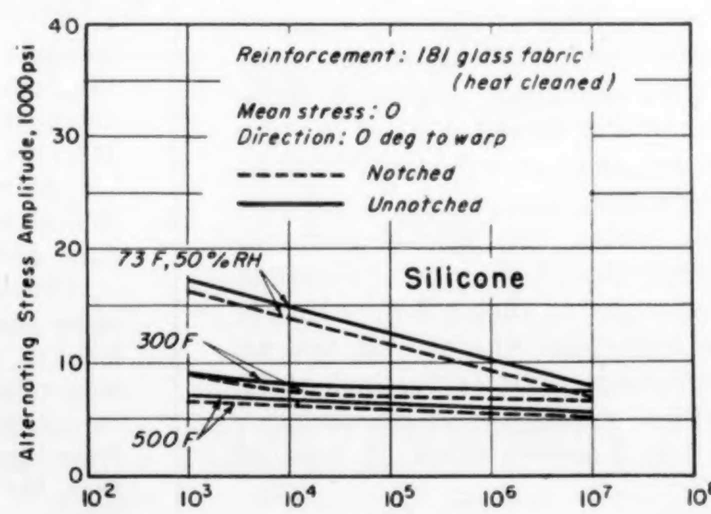


Fig 8—*Effect of heat on unnotched and notched silicone-glass laminate.*

peratures, tests conducted at different frequences might provide different results. For example, a lower test frequency would increase time of exposure and would probably lead to lower fatigue strengths, particularly at the larger numbers of cycles. Conversely, a higher test frequency might be expected to lead to higher fatigue strengths because of the reduced time of exposure.

Mean stress level

In practical applications of reinforced plastics, many conditions of stress can prevail. When a structural component is designed so that in a static condition it is essentially unstressed, and in service, stresses imposed are completely reversed (i.e., alternating tensile and compressive stresses are equal), the mean stress level of the component is zero. When the component is designed so that in a static condition it is stressed in either tension or compression, and, as before, service stresses are completely reversed, the mean stress level of the component is equivalent to the static prestress. When the alternating service stresses are not completely reversed, the mean stress level is equivalent to the difference in magnitude between the two stresses; e.g., if tensile stress amplitude is 15,000 psi and compressive stress amplitude is 10,000 psi, the mean stress level is 5000 psi in tension. The mean stress level may vary from zero to the ultimate strength of the material.

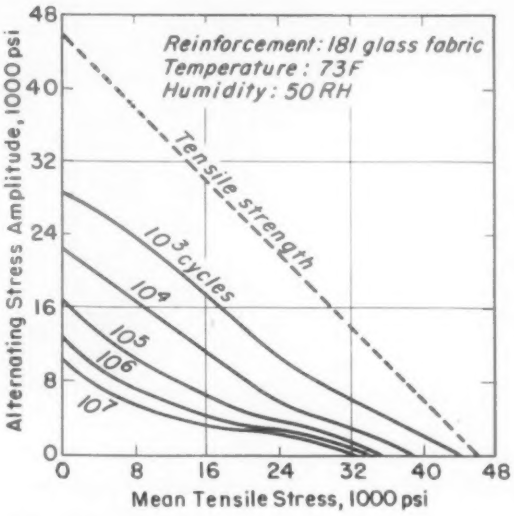


***Fig 9**—Effect of mean stress on alternating stress amplitude of unnotched heat resistant polyester-glass laminate at room temperature.*

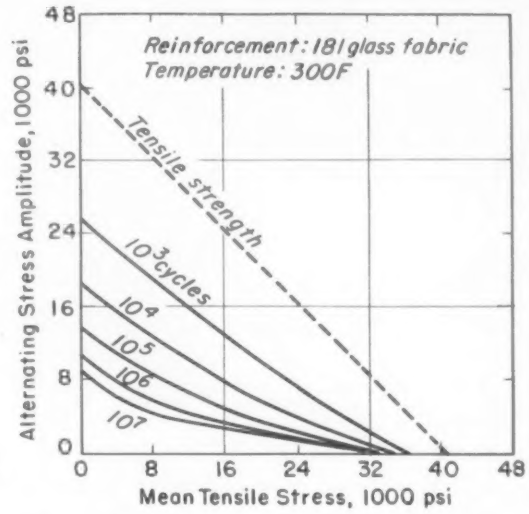


***Fig 10**—Effect of mean stress on alternating stress amplitude of unnotched heat resistant polyester-glass laminate at 300 F.*

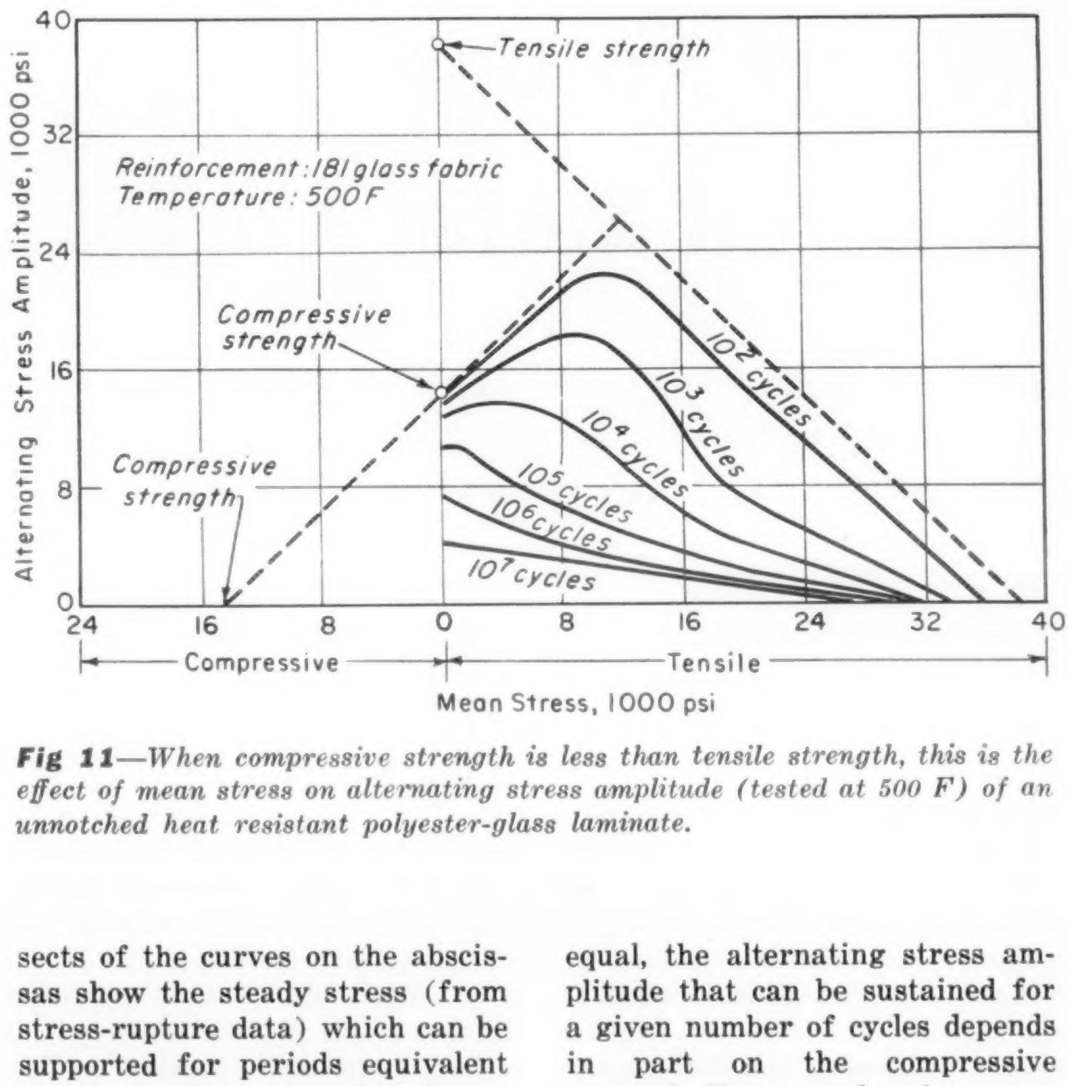
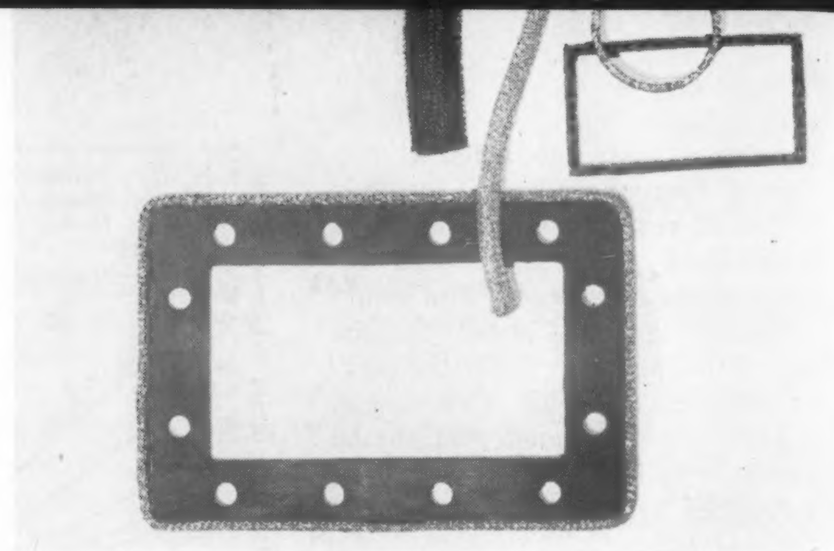


***Fig 11**—When compressive strength is less than tensile strength, this is the effect of mean stress on alternating stress amplitude (tested at 500 F) of an unnotched heat resistant polyester-glass laminate.*

Fig 9 and 10 show the relation between mean stress, alternating stress amplitude and time when other factors remain constant. Values are given for unnotched heat resistant polyester laminates reinforced with 181 glass cloth. Data in Fig 9 were obtained at 73 F and 50% relative humidity, whereas data in Fig 10 were obtained at 300 F. The ordinates of the graphs show alternating stress amplitude either in tension or compression, and the intersects of the curves on the ordinate represent fatigue strengths at zero mean stress at the number of cycles shown. The abscissas show mean stress level, and the intersects of the curves on the abscissas show the steady stress (from stress-rupture data) which can be supported for periods equivalent to the number of cycles shown. The curves show that, as mean stress levels increase, the amplitude of alternating stresses that can be borne in service decreases as number of cycles increases.

At elevated temperatures, laminated plastics do not always have equal tensile and compressive strength values. If tensile and compressive strength are not equal, the alternating stress amplitude that can be sustained for a given number of cycles depends in part on the compressive strength. For example, when mean stress is applied in tension, somewhat higher alternating stress amplitudes can be sustained at low levels of mean stress than at zero mean stress. This effect is shown by the curves in Fig 11, which plot both tensile and compressive strengths of an unnotched heat resistant polyester laminate (181 glass cloth) tested at 500 F.

***Fuel line filters** of knitted wire are resilient and do not require precise machining for side-wall fit.*



***Gaskets** of knitted wire have excellent conductivity and sufficient resiliency to produce tight joints on uneven surfaces, thereby preventing RF leakage.*

Where to Use Knitted Metal Parts

Here are eight new areas of application for knitted metal mesh—a group of materials having unique resiliency.

by Ralf L. Hartwell, *Executive Vice President, Metal Textile Corp.*

■ Knitted metal mesh has a number of unusual properties that make it suited for a variety of applications. Unlike woven wire (screen cloth), knitted mesh is produced by interlacing *loops* of wire. Because of this difference in structure, it has vastly different properties, particularly from the point of view of resiliency. Some special characteristics:

1. Knitting produces a mesh of interlocking loops, each loop acting as a small spring under loading and giving resiliency to the finished part. If stressing is not too severe, complete recovery of the shape results when stress is removed. In contrast, woven meshes cannot withstand similar deflection under load without permanent deformation.

2. Free volume can be controlled between 50 and 98%, since it is possible to knit a mesh having interstices of almost any desired size, regardless of wire diameter. With 98% free volume, wires are widely spaced; if a similar spacing were attempted with woven wire, the mesh would be practically impossible to handle because it would not retain its shape.

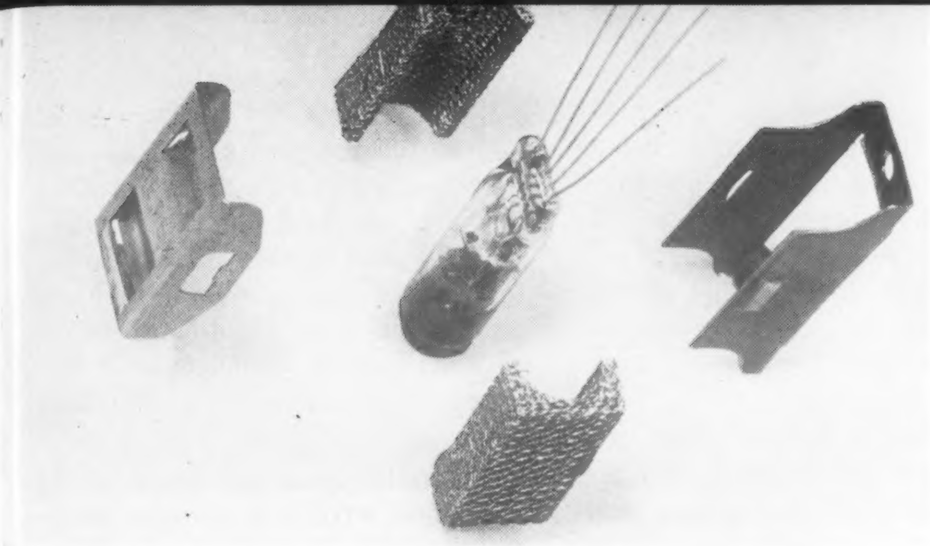
3. Asymmetrical mesh openings, resulting from knitting, are advantageous in certain electronic applications such as the special tube grids discussed later. The symmetrical mesh produced in weaving does not provide the same electronic characteristics. On the other hand, woven wire can be used for sieves, whereas knitted wire is not suitable for applications of this kind.

Knitted mesh parts are regularly made from wire in the range of 0.0005 and 0.025 in. in dia. Widely used materials are copper, aluminum, stainless steels, brasses, Monel and other nickel alloys.

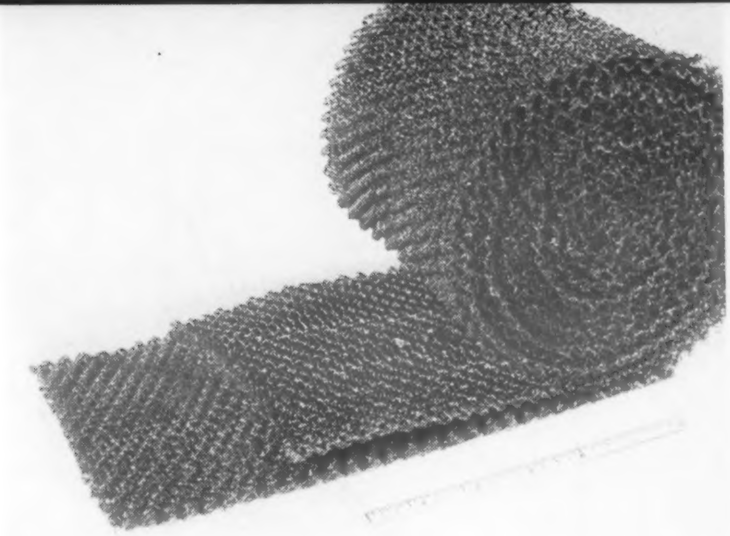
A number of applications of knitted mesh were discussed briefly in a previous article (M&M, Aug '51, p 61). These included a "mist eliminator" for separation of a liquid from a gas, separation of oil and water in de-oilers that operate on a coalescing principle, expansion joints for aircraft exhaust systems, radar reflectors, and contact electrodes for use in therapy. This article discusses some more recent applications.

Fuel line filters

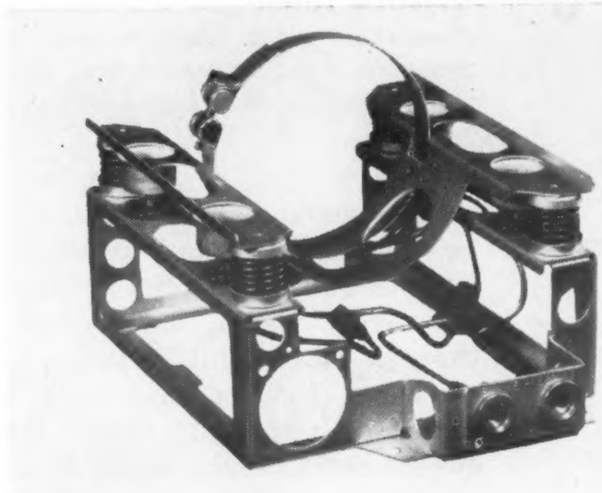
Conversion of diesel engine fuel line filters from metal powder parts to knitted wire has a number of advantages. Knitted wire filters are made from continuous lengths of wire; hence metallic particles cannot flake off. The resiliency of the knitted wire insures a good fit of the filter in its housing without costly machining of the seat. Knitted wire filters can be made less dense than sin-



Heat dissipation sleeves *for subminiature glass tube envelopes offer high efficiencies for tube cooling.*



Large diameter tower packing *for fractional distillation has low pressure drop and excellent theoretical plate efficiency.*



Robinson Aviation, Inc.

Shock and vibration control mountings *for airborne and industrial equipment use resilient cushions fabricated from stainless steel wire. Individual cushion assembly is shown at left; complete mounting at right.*

tered metal units and still remove the same size dirt particles. The additional free volume reduces the pressure drop across the unit and makes it less susceptible to plugging.

However, a sintered metal filter can be made in shapes that cannot be produced from knitted wire. For example, there are limitations in the ratio of height to diameter of a filter produced from knitted wire.

Laundry press pads

Until a few years ago laundry press pads were usually made of cotton. These pads harden under constant use, and to assure proper operation it is necessary to adjust the press every two weeks and to replace the pads every three months. Although cotton is still used to some extent, knitted Monel or stainless steel pads have taken over a great part of the field. Knitted wire pads are resilient enough to maintain proper pressing characteristics for periods of up to five years.

Vibration and shock absorbers

Rubber is commonly used in shock absorbers. However, rubber has definite temperature limitations and also becomes hard after aging. It also is affected by high frequency vibration, the mechanical energy being converted into heat that raises the temperature of the shock absorber and reduces its resiliency.

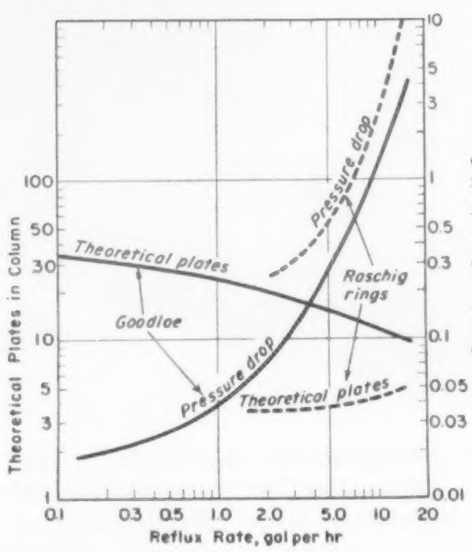
Metal shock absorbers have certain definite advantages that are just being recognized. They can be knitted and formed with free volumes ranging from 50 to 98%, and thus offer a great range of rigidity. By selecting the proper wire, you can make shock absorbers that maintain their resiliency from -90 F to 1000 F. They do not harden on aging, and high frequency vibrations do not raise the temperature enough to affect the spring action. Among present uses of knitted wire shock absorbers are mounts for aircraft communications, radar and other avionic equipment; and guided missiles.

Clamp liners

A number of materials can be used as tube clamp liners, including rubber, rubber-asbestos mixtures and asbestos. Rubber and rubber-asbestos are excellent materials but have definite temperature limitations. Asbestos does not have these limitations, but it does pack when subjected to high temperatures and vibration. Knitted wire has characteristics that make it very useful for tube clamp liners. Because parts can be knitted from any material available in wire form, selection can be made to meet a wide range of temperature conditions with the assurance that the liner will remain resilient. Further, its electrical conductivity permits grounding the conduit through the clamp liner itself.

Electronic shielding

Resilience and electrical conductivity, inherent in knitted wire mesh, are the two essential properties of a radio frequency shielding gasket. Because RF energy can leak through very small slits, the gasket must be resilient enough to make continuous contact, despite irregularities in



Goodloe tower packing *has high theoretical plate efficiency and low pressure drop per theoretical plate in comparison with Raschig rings.*

mating surfaces. The gasket must be conductive enough to absorb or reflect all the RF energy which otherwise would be radiated through the joint. These RF shielding gaskets are used to suppress radiation radio frequency interference which is unavoidably created by most types of electrically operated equipment.

Conductive rubber has been suggested for gaskets, but its conductivity is much too low for effective service. Woven wire has excellent conductivity but is not resilient enough to make a tight joint unless the mating surfaces are carefully machined.

Knitted wire gaskets combine excellent conductivity with sufficient resiliency to provide tight joints with uneven mating surfaces. These gaskets are generally knitted of aluminum, Monel or silver plated brass wire.

Selection of the material depends on the specific problem. For instance, aluminum gaskets are used in contact with aluminum and magnesium enclosures if strict adherence to galvanic corrosion specifications is required, as in certain highly specialized military equipment. Although Monel is the most corrosion resistant of the three materials, galvanic corrosion in contact with aluminum raises questions concerning its use with aluminum enclosures. In practice, however, the mass of the knitted Monel gasket is so much smaller than that of the aluminum that galvanic corrosion is minimized. Because of this effect, Monel shielding gaskets are used in contact with aluminum in much military electronic equipment.

Silver plated brass offers the best over-all conductivity. (Silver has low contact resistance, and brass is more conductive than Monel, but not as conductive as aluminum.) Although the combination is less corrosion resistant than Monel, its corrosion products are generally conductive. Gaskets made of silver plated brass offer the best compromise between high intrinsic conductivity and low contact resistance in average corrosive environments.

Heat dissipation

A major problem in subminiature assemblies of electronic tubes is removal of the heat generated in the tube; tubes that run cool outlast those running hot by a wide margin. One method of removing heat is to surround the glass tube envelope with a heat conductor. Many metals can be used for this purpose, but efficient results depend on close contact between the glass envelope and the conducting metal. Although spring clips and other spring-loaded devices have been used, the actual surface area in contact with the tube is restricted. Knitted wire sleeves are sufficiently resilient so that, when forced over the tube envelope, they produce a tight fit and make intimate contact with the glass at many points. Thus, a sleeve knitted from wire of high thermal conductivity becomes an efficient heat conductor.

A specific example is an assembly of 34 subminiature tubes in an airborne telemetering device. Knitted aluminum wire sleeves 1/8 in. thick having an internal dia of 3/8 in. were used on these tubes. The sleeves were covered with silver plated copper foil and clamped with a spring bracket. In a test run, with the assembled unit operating at a stabilized ambient temperature of 130 F, the temperature inside the unit reached 220 F. Temperatures on the shielded tubes reached 275 F—well within safe operating temperature ranges—whereas temperatures on unshielded tubes reached 345 F—much above the maximum permissible (300 F).

Electron tube grids

Knitted wire mesh, when made from fine wire, has unique properties which make it very useful as a grid material in some special electron tubes.

Specifically:

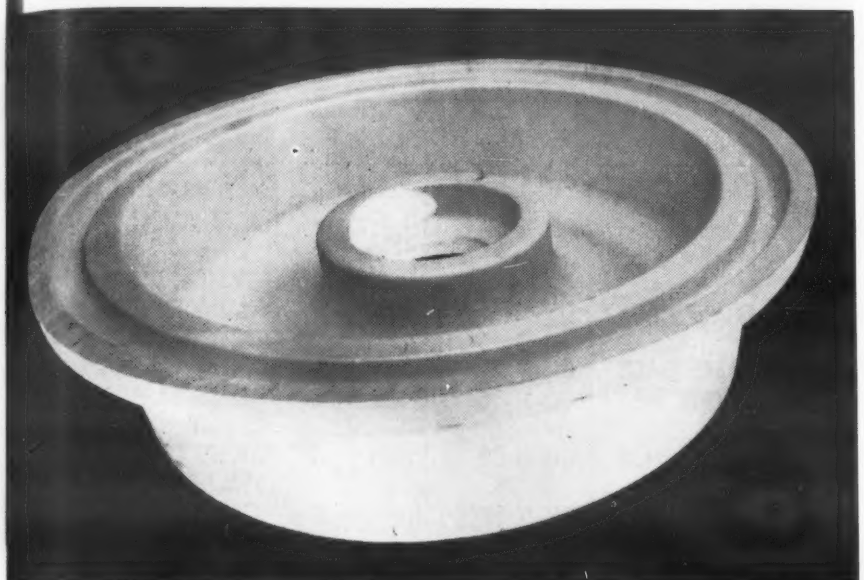
1. The mesh has low "shadow." A mesh knitted from 0.0005-in. dia tungsten casts only 5% shadow, yet is mechanically stable and easily handled.
2. The mesh has asymmetrical openings. This means zoning patterns will not form when successive layers of mesh are used. This desirable lack of symmetry is possible without loss of control of the number of mesh openings per in.
3. The mesh will maintain a plane despite temperature variations. In woven wire, the wires are essentially straight and the entire mesh must bulge out of plane to compensate for increased wire length due to expansion with increasing temperature. In knitted mesh the loop shape changes slightly to compensate for increased length and the mesh maintains a constant plane.

Tower packing

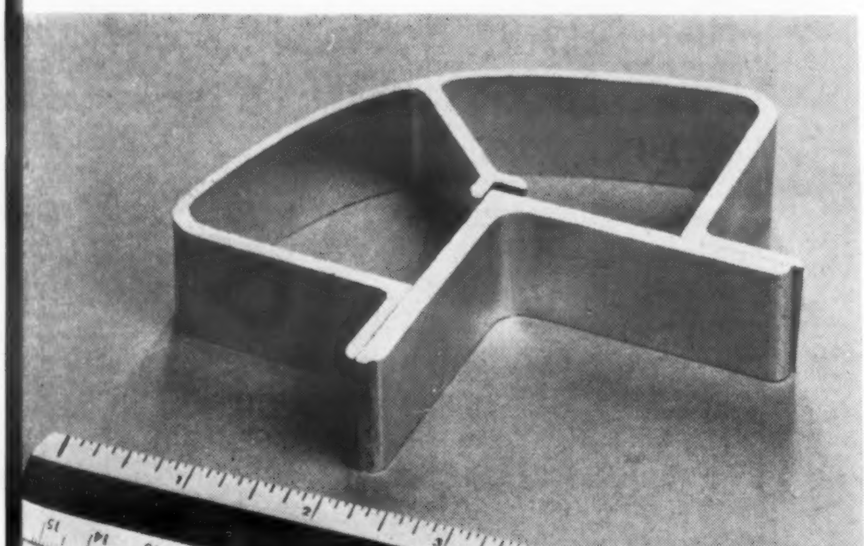
Many different materials are used as tower packings to promote contact between liquids and vapors or gases. Cylindrical cartridges made by rolling together two crimped, flattened tubes of knitted wire mesh provide an outstanding capillary type tower packing. The packing has good capacity, high theoretical plate efficiency, quite a low pressure drop per theoretical plate, as shown by comparison with Rashig rings in an accompanying graph.

The resilient nature of this packing, called Goodloe packing, provides a good fit in columns that are not exactly of the specified diameter, are tapered, or are out of round.

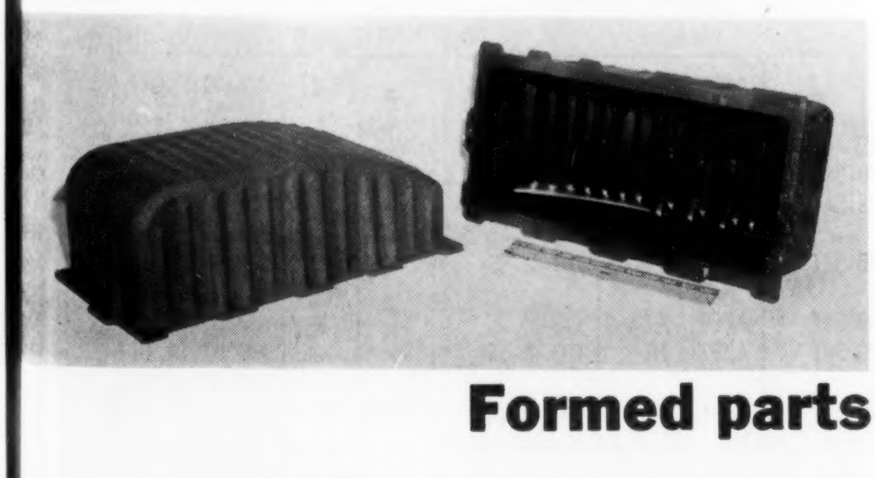
Castings



Forgings



Extrusions



Formed parts

Materials
in Design Engineering

Manual No. 139—July 1957

Magnesium and Its Alloys

by M. W. Mote and R. J. Jackson,
Battelle Memorial Institute

Increased civilian use of magnesium since World War II has resulted from introduction of new alloys, development of the hot chamber die casting process, improved finishing systems, and large-scale production of sheet and plate. Here is an up to date 20-page manual on the properties, fabrication and uses of the magnesium alloys now commercially available.

Types and Forms Available

Unalloyed magnesium has little useful application. Physical properties such as conductivity, reflectivity and appearance do not promote its use as they do for aluminum or copper in many applications. For this reason most available forms of magnesium are alloys, the exception being pure magnesium pig for foundry purposes.

Alloying elements commonly used in magnesium include aluminum, manganese, zinc, zirconium, Mischmetal (or rare earths) and thorium. A manganese alloy has been available in wrought form for a number of years and finds many applications where formability is of paramount importance. Aluminum-zinc alloys, both wrought and cast, has been used for many years to good advantage. More recently, the rare earth metals and zirconium have been added to promote elevated temperature properties and grain refinement. Proper combinations of these alloying elements provide alloys suitable for castings, for forgings and extrusions, and for sheet and plate. Many of these alloys are heat treatable; others can be cold worked to improve mechanical properties.

Standard designations for magnesium alloys are given in Table 1, and nominal compositions in Table 2.

Engineering Properties

Properties of magnesium alloys depend on the configuration and size of the desired part as well as on the composition and history of the material. For example, 1/8-in. sheet generally shows greater tensile strength and ductility than 1/2-in. plate of the same composition; and a cast section 1/4 in. thick is generally superior to the

TABLE 1—DESIGNATIONS FOR MAGNESIUM AND MAGNESIUM ALLOYS

ASTM			Federal or Military			AMS No.	SAE No.	Proprietary Nomenclature Used Prior to Adoption of Standard Nomenclature
Alloy and Temper		Spec No.	Alloy and Temper		Spec No.			
Ingot								
—	—	B 92-52	—	—	Mil-M-20161	—	—	AM2S
AM80A	—	B 93-52T	—	—	—	—	—	AM241, A
AM100A	—	B 93-52T	—	—	—	—	—	AM240, G
AZ63A	—	B 93-52T	—	—	—	—	—	AM265, 630, H
AZ91A	—	B 93-52T	—	—	—	—	—	AM263, 910, R
AZ91B	—	B 93-52T	—	—	—	—	—	910
AZ91C	—	B 93-52T	—	—	—	—	—	AMA263, 910
AZ92A	—	B 93-52T	—	—	—	—	—	AM260, 920, C
M1B	—	B 93-52T	—	—	—	—	—	AM403, M
AZ81[a]	—	—	—	—	—	—	—	AZ81XA
Sand Castings								
AM80A	-F	B 80-54T	—	—	—	—	—	A-F, A8
AM80A	-T4	B 80-54T	—	—	—	—	—	A-T4, AM241-T4
AM80A	-T6	B 80-54T	—	—	—	—	—	
AM100A	-T6	B 80-54T	—	—	—	—	—	AM240-T61
AZ63A	-F	B 80-54T	AZ63	AC	QQ-M-56	4420	50	AM265-F[b], 630, H-F, 15A, AZG
AZ63A	-T5	B 80-54T	AZ63	ACS	QQ-M-56	—	—	AM265-T51, H-T5
AZ63A	-T4	B 80-54T	AZ63	HT	QQ-M-56	4422	—	AM265-T4, H-T4, 15A-ST
AZ63A	-T6	B 80-54T	AZ63	HTA	QQ-M-56	4424	—	AM265-T6, H-T6, 15A-STA
AZ63A	-T7	—	AZ63	HTS	QQ-M-56	—	—	AM265-T7
AZ91C	-F	B 80-54T	AZ91	AC	QQ-M-56	—	504	AMA263-F, 910
AZ91C	-T4	B 80-54T	AZ91	HT	QQ-M-56	—	—	AMA263-T4
AZ91C	-T6	B 80-54T	AZ91	HTA	QQ-M-56	—	—	AMA263-T6
AZ92A	-F	B 80-54T	AZ92	AC	QQ-M-56	—	500	AM260-F[c], 920, C-F, 56
AZ92A	-T5	B 80-54T	AZ92	ACS	QQ-M-56	—	—	AM260-T51, C-T5
AZ92A	-T4	B 80-54T	AZ92	HT	QQ-M-56	—	—	AM260-T4, C-T4, 56-ST
AZ92A	-T6	B 80-54T	AZ92	HTA	QQ-M-56	4434	—	AM260-T6, C-T6, 56-STA
AZ92A	-T7	—	AZ92	HTS	QQ-M-56	—	—	AM260-T7
EK30A	-T6	B 80-54T	—	—	—	—	—	AMA130-T6
EK41A	-T5	B 80-54T	—	—	—	—	—	517, AMA130-T5
EK41A	-T6	B 80-54T	—	—	—	—	—	517, AMA130-T6
EZ33A	-T5	B 80-54T	EZ33A	-T5	MIL-M-9433	—	—	AMA131-T5, ZRE1
MIB	-F	B 80-54T	M1	AC	QQ-M-56	—	—	AM403-F, M
ZK51A	-F	—	ZK51	-F	MIL-M-8213	—	—	Z5Z
ZK51A	-T5	B 80-54T	ZK51	-T5	MIL-M-8213	—	—	520, Z5Z
ZK61A	-T6	B 80-54T	—	—	—	—	—	
AM40[a]	-F	—	—	—	—	—	—	AM244-F
HK31A	-T6	—	—	—	—	—	—	HK31XA-T6
HZ32A	-T5	—	—	—	—	—	—	HZ32XA-T5, ZT1
ZH62[a]	-T5	—	—	—	—	—	—	ZH62XA-T5, TZ6
ZE41[a]	-T6	—	—	—	—	—	—	RZ5
AZ81[a]	-T4	—	—	—	—	—	—	AZ81XA-T4
AM120[a]	-F	—	—	—	—	—	—	AM246-F
AM120[a]	-T51	—	—	—	—	—	—	AM246-T51
Permanent Mold Castings								
AM100A	-F	B 199-54T	A10	AC	QQ-M-55	—	502	AM240-F, G-F
AM100A	-T5	B 199-54T	—	—	—	—	—	AM240-T51
AM100A	-T4	B 199-54T	A10	HT	QQ-M-55	—	—	AM240-T4, G-T4
AM100A	-T61	B 199-54T	A10	HTA2	QQ-M-55	—	—	AM240-T61,G-T61
AM100A	-T6	B 199-54T	A10	HTA1	QQ-M-55	—	—	AM240-T6, G-T6
AM100A	-T7	—	—	—	—	—	—	AM240-T7
AZ92A	-F	B 199-54T	AZ92	AC	QQ-M-55	—	503	AM260-F[c], 920, C-F, 15B
AZ92A	-T5	B 199-54T	AZ92	ACS	QQ-M-55	—	—	AM260-T51, C-T5
AZ92A	-T4	B 199-54T	AZ92	HT	QQ-M-55	—	—	AM260-T4, C-T4, 15B-ST
AZ92A	-T6	B 199-54T	AZ92	HTA	QQ-M-55	4484	—	AM260-T6, C-T6, 15B-STA
AZ92A	-T7	—	—	—	—	—	—	AM260-T7

TABLE 1—(Continued)

ASTM			Federal or Military					Proprietary Nomenclature Used Prior to Adoption of Standard Nomenclature
Alloy and Temper		Spec No.	Alloy and Temper		Spec No.	AMS No.	SAE No.	
Die Castings								
AM100B	—	B 94-52	—	—	—	—	—	
AZ91A	—	B 94-52	—	—	QQ-M-38	4490	500	AM263-F, 910, R, 15C, AZ91
AZ91B	—	B 94-52	—	—	—	—	501A	910, RC
AM10[a]	—	—	—	—	—	—	—	130
Extrusions								
AZ31B	-F	B 107-53T	AZ31B	—	QQ-M-31a	—	52	AMC52S, FS1
AZ61A	-F	B 107-53T	AZ61A	—	QQ-M-31a	4350	520	AMC57S, J1
AZ80A	-F	B 107-53T	AZ80A	-F	QQ-M-31a	—	523	AMC58S-F, 01-F
AZ80A	-TS	B 107-53T	AZ80A	-T5	QQ-M-31a	—	—	AMC58S-T51, 01-T5
M1A	-F	B 107-53T	M1	—	QQ-M-31a	—	522	AM3S, M
ZK60A	-F	B 107-53T	ZK60A	-F	QQ-M-31a or MIL-M-5354A	4352	524	ZK60A-F, AMA76S-F
ZK60A	-T5	B 107-53T	ZK60A	-T5	QQ-M-31a or MIL-M-5354A	4352	524	ZK60A-T5, AMA76S-T5
MZ10[a]	—	—	—	—	—	—	—	MF
AZ51[a]	—	—	—	—	—	—	—	JS1
Mg99.8[a]	—	—	—	—	—	—	—	AM2S
Tubing								
AZ31B	—	B 217-53T	AZ31X	—	WW-T-825	—	52	AMC52S-F, FS1
AZ61A	—	B 217-53T	AZ61X	—	WW-T-825	4350	520	AMC57S-F, J1
M1A	—	B 217-53T	M1	—	WW-T-825	—	522	AM3S, M
ZK60A	-F	B 217-53T	—	—	—	4352	524	AMA76S-F
ZK60A	-T5	B 217-53T	—	—	—	4352	524	AMA76S-T5
Mg99.8[a]	—	—	—	—	—	—	—	AM2S
MZ10[a]	—	—	—	—	—	—	—	MF
AZ51[a]	—	—	—	—	—	—	—	JS1
Forgings								
AZ31B	—	B 91-54T	—	—	QQ-M-40	—	—	FS1
AZ61A	—	B 91-54T	AZ61A	—	QQ-M-40	4358	531	AMC57S, J1
AZ80A	-F	B 91-54T	AZ80A	-F	QQ-M-40	4360	532	AMC58S, 01-F
AZ80A	-T5	B 91-54T	AZ80A	-FA	QQ-M-40	—	—	AMC58S-T5, 01-T5
TA54A	—	B 91-54T	TA54A	—	QQ-M-40	—	53	AM65S
ZK60A	—	—	—	—	—	—	—	AMA76S-F
ZK60A	-T5	B 91-54T	ZK60A	-FA	QQ-M-0040	4362	—	AMA76S-T5
M1A	—	—	M1A	—	QQ-M-40	—	533	AM3S, M
Sheet								
AZ31A	-0	B 90-51T	—	-A	QQ-M-44	4375	510	FS1-0, AMC52S-0
AZ31A	-F	—	—	—	—	—	—	FS1-F
AZ31A	-H10	—	—	—	—	—	—	FS1-H10
AZ31A	-H11	—	—	—	—	—	—	FS1-H11
AZ31A	-H23	—	—	—	—	—	—	FS1-H23
AZ31A	-H24	B 90-51T	—	-H	QQ-M-44	—	—	FS1-H24, AMC52S-H24
AZ31A	-H26	—	—	—	—	4376	—	FS1-H26
AZ31B	-0	—	—	—	—	—	—	FS1W-0
AZ31B	-H24	—	—	—	—	—	—	FS1W-H24
M1A	-F	—	—	—	—	—	—	M-F, AM3S-F
M1A	-0	B 90-51T	—	-A	QQ-M-54	4370	51	M-0, AM3S-0
M1A	-H24	B 90-51T	—	-H	QQ-M-54	—	—	M-H24, AM3S-H24
AZ51[a]	—	—	—	—	—	—	—	JS1-0, JS1-F JS1-H24
MZ10[a]	—	—	—	—	—	—	—	MF-0, MF-F MF-H24
HK31A-T6	—	—	—	—	—	—	—	HK31XA-T6
HM21XA-T8	—	—	—	—	—	—	—	HM21XA-T8

[a]Alloys whose composition is not shown in ASTM specifications. Designation follows ASTM rules but no final letter is given.
[b]AM266 has similar nominal composition but wider impurity limits.
[c]AM262 has similar nominal composition but wider impurity limits.

same composition in a 1-in. section. Similarly, the strength of extrusions often reflects the method of extrusion and the degree of reduction. Because of the importance of section size, data listed in Tables 3, 4 and 5 are merely typical and cannot be considered design data.

Mechanical properties are generally determined by ASTM standard methods. Properties of casting alloys are usually determined on separately cast test bars, with most purchasing specifications requiring that test coupons cut from the casting have a specified proportion of the properties exhibited by these bars. Based on experience, it is safe to generalize that the thinner the cast section, the better its properties. Since the data in this article were obtained on cast-to-size ½-in. round tensile bars, thinner cast sections may be expected to show better properties than those given here. Adherence to close tolerances on the design strength level probably will require testing of complete castings rather than tensile specimens.

Tensile and creep properties

Selected tensile data for magnesium alloys at room and elevated temperatures are given in Table 3. For various reasons related to crystal structure, modes of deformation and degree of preferred crystal orientation, compressive yield strengths of high strength wrought alloys are often as low as 85% of the tensile yield strength. In many wrought alloys, however, differences are less significant at elevated temperatures. Most cast alloys exhibit essentially equivalent tensile and compressive yield strengths.

Elevated temperature values reported in Table 3 are for short time tensile tests. Because metallurgical changes can take place at these temperatures, the strengths at temperature after exposure for periods up to 1000 hr are interesting. Although it is necessary for some applications to know the effect of such exposures on room temperature properties, these requirements are too specific to attempt to characterize here. It

suffices to note that many of the newer alloys are adequately stable at temperatures up to 500 F for prolonged engineering service, and that recent thorium alloys exhibit excellent stability up to 700 F.

Another measure of serviceability at elevated temperatures is creep resistance. Tables 4 and 5 show the creep properties of a number of cast and wrought alloys. Casting alloys for elevated temperature service have been available for some time. Only recently have the HK and HM wrought alloys been produced. Worthy of special note is a comparison drawn at the 1957 ASM Western Metal Congress between HK31A-T6 and HM21XA-T8. As shown in Table 5, the latter alloy exhibits superior creep resistance at 500 F and 600 F. However, for applications shorter than 30 min HK31A-T6 is better than HM21-XA-T8. Such short time applications are of increasing interest as newer airframe and missile designs are developed.

Fatigue resistance

In common with other nonferrous alloys, magnesium does not have an endurance limit. However, the slope of the S-N curve at 10^6 or 10^7 cycles is quite low, and safe limits of cyclic stress can be approximated. Available data indicate that fatigue resistance of alloys is related to differences in static strength. One set of fatigue test data indicates that the stress to produce failure at 10^7 cycles is between 0.45 and 0.49 of ultimate strength for AZ31, AZ80 and ZK60 wrought alloys.

Treatments that produce residual surface compressive stresses may be used to improve the fatigue resistance of magnesium alloys. Shot peening should employ round shot at least 3/16 in. in dia. Care must be taken to prevent formation of surface notches, e.g., by use of cut wire shot.

Service experience indicates that magnesium alloys are more notch sensitive than low strength steels, and stress raisers must be avoided where cyclic loading is

TABLE 3—TYPICAL TENSILE PROPERTIES

Temperature ➤		70 F			200 F		
Alloy Designation ▼							
ASTM	Temper	Ten Str, ksi	Yld Str, ksi	Elong, %	Ten Str, ksi	Yld Str, ksi	Elong, %
		SAND CASTINGS					
AM80A	T4	39.0	15.0	9	—	—	—
AM100A	T6	40.0	19.0	1	—	—	—
AZ63A	T6	40.0	19.0	5	38.0	16.5	11
AZ91C	T6	40.0	21.0	6	—	—	—
AZ92A	T6	43.4	26.0	2	41.3	22.0	25
EK30A	T6	23.0	16.0	3	22.0	15.0	4
EK41A	T6	25.0	18.0	3	23.0	16.0	5
EZ33A	T5	23.0	16.0	3	23.0	15.0	6
ZK51A	T5	38.0	24.0	7	30.0	21.0	12
ZK61A	T6	39.5	23.9	5	—	—	—
HK31A	T6	30.8	16.2	6	—	—	—
HZ32A	T5	30.7	17.1	5	—	—	—
ZH62	T5	40.0	25.0	10	33.0	23.0	20
ZE41		30.0	19.0	3	—	—	—
HK21	T6	32.1	13.9	8	—	—	—
		FORGINGS					
AZ80A	T6	50.0	34.0	5	43.0	27.0	15
M1A	F	33.6	18.8	12	23.1	13.8	26
		EXTRUSIONS					
AZ31B	F	39.9	28.6	17	34.8	22.0	20
AZ61A	F	48.8	33.1	14	42.3	26.4	21
AZ80A	T6	56.5	40.5	4	48.5	32.1	20
M1A	F	39.6	30.9	8	27.0	21.3	15
ZK60A	T5	53.0	44.0	11	—	32.0	—
HM31A	F	43.0	40.0	11	—	—	—
		SHEET					
AZ31B	H24	41.0	32.0	14	34.0	24.0	35
M1A	H24	36.0	27.0	10	29.7	26.7	8
HK31A	T6	37.0	21.0	14	—	—	—
HM21XA	T8	34.0	25.0	10	—	—	—

TABLE 2—NOMINAL COMPOSITIONS OF COMMERCIAL MAGNESIUM-BASE ALLOYS

Designation		Composition, %					
ASTM	Equivalent	Al	Zn	Mn	Rare Earths	Th	Zr
M1A	M	—	—	1.20	—	—	—
AM80A	A, A8	8.5	—	0.15	—	—	—
AM100A	G	10.0	—	0.10	—	—	—
AZ31B	FS1	3.0	1.0	0.20	—	—	—
AZ51	JS1	5.0	1.0	0.25	—	—	—
AZ61A	J1	6.5	1.0	0.15	—	—	—
AZ63A	H	6.0	3.0	0.15	—	—	—
AZ80A	O1	8.5	0.5	0.15	—	—	—
AZ81	None	7.6	0.7	0.13	—	—	—
AZ916	None	8.7	0.7	0.13	—	—	—
AZ92A	C	9.0	2.0	0.15	—	—	—
EK30A	None	—	—	—	3.0	—	0.3
EK41A	None	—	—	—	4.0	—	0.6
ZK60A	None	—	5.7	—	—	—	0.55
ZK61	None	—	6.0	—	—	—	0.7
HK31A	None	—	—	—	—	3.0	0.7
HM21XA	None	—	—	0.60	—	2.0	—
EZ33A	ZRE1	—	2.7	—	3.0	—	0.7
ZE41	RZ5	—	4.0	—	1.2	—	0.7
ZK51A	Z5Z	—	4.6	—	—	—	0.7
ZH62	TZ6	—	5.0	—	—	1.8	—
HZ32A	ZT1	—	2.1	—	—	3.0	0.7

OF MAGNESIUM BASE-ALLOYS AT ROOM AND ELEVATED TEMPERATURES

300 F			400 F			500 F			600 F		
Ten Str, ksi	Yld Str, ksi	Elong, %	Ten Str, ksi	Yld Str, ksi	Elong, %	Ten Str, ksi	Yld Str, ksi	Elong, %	Ten Str, ksi	Yld Str, ksi	Elong, %
21.0	10.0	16	14.0	8.0	22	9.5	5.0	40	—	—	—
24.0	9.0	4	17.0	6.5	25	12.0	4.0	45	8.5	2.5	60
27.0	14.2	15	17.5	12.0	19	12.0	8.8	15	7.3	6.0	20
27.0	14.0	40	17.0	12.0	40	—	—	—	—	—	—
28.0	18.0	35	16.9	10.9	36	11.3	7.4	33	7.8	5.1	49
21.0	14.0	8	20.0	12.0	13	18.0	11.0	30	12.0	8.0	70
23.0	16.0	8	22.0	14.0	12	20.0	12.0	19	13.0	9.0	53
22.0	14.0	10	21.0	11.0	20	18.0	10.0	31	12.0	8.0	50
23.0	17.0	14	17.0	13.0	17	12.0	9.0	16	8.0	6.0	16
24.6	17.7	21	18.1	15.1	22	—	—	—	—	—	—
—	—	—	23.9	12.8	16	22.1	11.6	20	19.1	10.8	21
—	—	—	19.3	13.0	30	16.4	11.7	38	12.7	9.5	38
26.0	20.0	24	19.0	15.0	28	14.0	10.0	30	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	21.7	11.6	19	20.1	11.6	23	17.4	9.8	24
31.0	20.7	30	22.0	15.0	49	14.0	8.0	83	9.0	5.0	123
19.9	12.0	31	17.2	9.1	34	10.1	5.9	87	6.0	3.8	140
24.7	14.5	38	17.0	9.5	65	15.0	5.5	55	10.0	—	90
30.4	20.2	40	21.4	14.7	42	12.9	8.2	64	7.9	5.1	70
33.6	21.4	41	21.6	14.7	49	13.6	7.8	83	8.7	4.7	123
21.3	15.7	18	18.8	11.7	25	13.0	7.5	60	9.0	5.4	93
—	24.0	—	15.0	12.0	84	6.0	4.0	177	—	—	—
28.0	27 0	28	25.0	24.0	31	22.0	21.0	24	17.0	16.0	22
22.0	13.0	58	13.0	8.0	82	8.0	5.0	92	6.0	2.0	136
25.0	21.2	16	16.0	10.0	42	10.0	4.0	86	5.0	3.0	143
25.0	16.0	19	23.0	15.0	19	20.0	14.0	21	18.0	12.0	22
—	—	—	18.0	17.0	30	16.0	15.0	25	14.0	12.0	—

TABLE 4—SOME CREEP PROPERTIES OF CAST MAGNESIUM ALLOYS

	Stress to Produce Indicated Extension in 1000 Hr, ksi														
Temperature, F ➤	200			300			400			500			600		
Extension, % ➤	0.1	0.5	1.0	0.1	0.5	1.0	0.1	0.5	1.0	0.1	0.5	1.0	0.1	0.5	1.0
AZ63A T6	3.5	10.1	12.3	1.6	4.2	6.3	—	—	—	—	—	—	—	—	—
AZ92A T6	4.2	10.5	14.2	1.5	4.8	6.4	—	0.8	1.3	—	—	—	—	—	—
EK30A T6	—	—	—	—	—	—	4.4	6.7	7.3	1.5	2.3	2.5	0.7	1.0	1.1
EK41A T6	—	—	—	—	—	—	4.4	7.4	7 9	—	—	—	1.1	1.3	1.4
EZ33A T5	—	—	—	—	—	—	4.3	8.3	9.2	1.6	2.6	3.1	0.7	1.1	1.2
ZK51A T5	3.5	12.0	14.0	2.1	7.1	9.0	1.2	3.5	4.9	—	—	—	—	—	—
HK31A T6	—	—	—	—	—	—	5.4	14.0	15.8	3.1	6.8	7.6	0.9	1.4	1.6
HZ32A T5	—	—	—	—	—	—	4.8	9.8	10.4	3.5	6.5	6.9	1.9	2.9	3.2

expected. Design recommendations usually call for generous radii and fillets, careful joining and avoidance of surface imperfections. These requirements are probably no more severe than for other materials, although magnesium alloys are probably used more frequently very near the design stress level.

Physical properties

Some of the physical properties of magnesium are given in Table 6. Although the melting point of pure magnesium is 1200 F, com-

TABLE 5—SOME CREEP PROPERTIES OF WROUGHT MAGNESIUM ALLOYS

	Stress to Produce Indicated Extension in 100 Hr, ksi								
Temp, F ➤	200			300			400	500	600
Ext % ➤	0.1	0.5	1.0	0.1	0.5	1.0	0.5	0.5	0.5
AZ31B H24	2.6	7.2	9.6	0.6	1.6	2.3	—	—	—
M1A H24	3.9	11.5	14.0	1.1	3.0	4.0	—	—	—
AZ61A F	3.8	7.4	14.4	—	1.3	3.2	—	—	—
HK31A H24	—	—	—	—	19.0	—	9.6	—	—
HK31A T6	—	—	—	—	—	—	14.0	8.2	2.2
HM21XA T8	—	—	—	—	—	—	13.5	9.0	6.0

TABLE 6—PHYSICAL PROPERTIES OF MAGNESIUM

Density, lb/cu in	0.626
Melting Point, F	1200
Boiling Point, F	2025
Ther Cond (68 F), Btu/hr/sq ft/ft/°F	41-90[a]
Coef of Ther Exp (100 F), per °F	14×10^{-6}
Specific Heat (68 F), Btu/lb/°F	0.25
Elec Cond (vol), % IACS	10-38.6[a]
Magnetic Permeability, cgs	1.000012
Modulus of Elasticity, psi	6.5×10^6
Modulus of Rigidity, psi	2.4×10^6
Poisson's Ratio	0.35

[a]Depends on alloy and degree of cold work.

mon alloying additions can lower the melting point to 830 F, a factor that may require consideration in hot working operations.

Probably the outstanding physical property of magnesium is its light weight. If magnesium alloys are assigned an arbitrary value of 1.0, aluminum alloys have a relative weight of 1.6, zinc alloys 3.9, cast iron 4.0, steels 4.4, brass 4.7, and both bronze and nickel 4.9.

Strength-density ratios

A comparison of the strength of magnesium alloys on a volume basis with other structural materials would not lead to its selection as an engineering material. For many applications, however, weight of a structure of equivalent resistance to applied load is the most important criterion.

On a strength-weight basis, high strength magnesium alloys are generally superior, at room temperature, to all other common structural materials except very high strength aluminum alloys. The newer thorium-bearing alloys have no peer among common structural materials at temperatures between 300 and 600 F, although recently developed precipi-

Magnesium Today

Traditionally magnesium has been a war material. Its first applications were for incendiary purposes, and the development of structural applications of magnesium was slow. World War II gave a tremendous push to this development, but applications were almost entirely for military purposes. It appears, however, that structural magnesium has come of age at last, as shown by the following figures on shipments of magnesium alloys for structural purposes:

	Military (Aircraft and Missiles)	Nonmilitary (Consumer goods, Tools, Vehicles, etc.)
1954	10,100 tons	7,850 tons
1955	11,500 tons	12,700 tons

Nonmilitary applications now exceed military applications for the first time. Figures for 1956 are not available, but the trend established over recent years indicates that nonmilitary use should expand at increasing rates. Though nonstructural applications (sacrificial anodes, treatment of cast iron, alloying in other metals, etc.) have consumed metal at a rate that has increased some 8 to 10% per year for the past five years, the proportion of total consumption represented by these applications has slowly declined, and in 1956 probably accounted for about 60%.

Among the principal reasons for increased consumption of structural alloys in nondefense uses are the technological advances made since World War II. These include development of hot chamber die casting processes, improved finishing systems (including electrochemical coatings and electroplating), impact extrusion techniques, and large scale production of rolled plate and sheet. Other reasons for increased use of magnesium, however, are better recognition of the metal's inherent advantages and increased experience with its production and fabrication. Light weight has promoted increasing use in portable power tools such as saws and hoists, appliances, and electric motors. Light weight and rigidity have made magnesium alloys particularly applicable to dock boards and tooling plates and fixtures. Excellent appearance and resistance to atmospheric corrosion have led to its use in high quality lightweight tools, luggage, ladders and a host of similar products.

Development of new alloys has led to increased interest in the use of magnesium in aircraft at temperatures in the range of 300 to 600 F, where certain magnesium alloys have strength and stiffness for a given weight generally superior to those of other materials. Probably missiles and similar military matériel will demand increasing application of magnesium alloys, because weight savings result in tremendous improvements in performance characteristics of such devices.

Perhaps the most definite mark of the maturity of magnesium technology is the interest displayed by users in solving their own technical problems. Until recent years fabricators have relied almost entirely on Dow Chemical Co. for the solution of production and fabrication problems. Now the inherent advantages of magnesium are well enough recognized that others, including various Government agencies, spend considerable effort in process and material development. Brooks & Perkins, a leading fabricator for several years, has pioneered in many developments and recently announced a joint venture with Dominion Magnesium Ltd. of Canada that will provide a new source of primary magnesium. The resulting technological and business competition should provide further stimulus to the development of magnesium and its alloys for structural application.

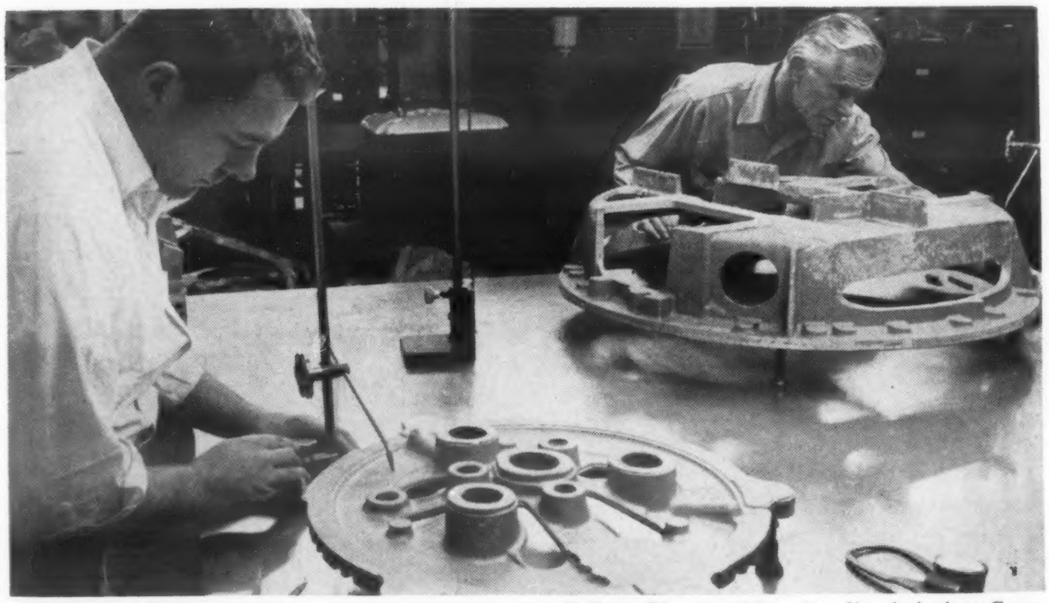
Approximate Corrosion Resistance of Bare Magnesium

Recommended for . . .		Recommended for (cont'd) . . .	
Alcohol (butyl)	Ethylene glycol	Sulfur	Tar
Alkali metal hydrides	Ethyl acetate	Sodium carbonate	Turpentine
Ammonium hydroxide	Fluorine	Sodium silicate	Water (distilled)
Arsenates	Fluorides (most)	**Not recommended for . . .**	
Asphaltum	Gasoline (lead-free)	Alcohol (methyl)	Hydrogen peroxide
Acetylene	Gas (illuminating)	Acids (not otherwise listed)	Ink (iron)
Benzene	Grease (acid-free)	Acetone	Mercury
Bichromates (most)	Hydrofluoric acid (>5%)	Beer	Milk
Borax solutions	Ink (dye)	Chlorine	Metal salts (not otherwise listed)
Cyanides (most)	Kerosene	Carbonated waters	Nitrates
Carbon dioxide	Lanolin	Hydrofluoric acid (<5%)	Water (sea, tap)
Carbon monoxide	Linseed oil	**Service trial warranted for . . .**	
Carbon bisulfide	Oxygen	Alcohol (ethyl)	Formaldehyde
Carbon tetrachloride	Oils (chloride-free)	Aniline	Gasoline (leaded)
Chloroform	Phenol	Dry cleaning fluids	Phosphoric acid
Chromates (most)	Permanganates (most)		
Chromic acid	Phosphates (most)		
Diethylene glycol	Rubber		

Source: Brooks and Perkins, Inc.

tation hardening steels and titanium alloys are measurably superior on a strength-weight basis over all ranges of temperature.

For many structural applications rigidity is of paramount importance. The modulus-density ratio of all common structural metals is almost a constant. The low modulus of magnesium is offset by its low density, and in many configurations the permissible increase in section size provides improved rigidity because of its geometry. Therefore, when stiffness or resistance to buckling is a design criterion, magnesium sections of equivalent resistance are often lighter.



Eclipse-Pioneer Div., Bendix Aviation Corp.

Closer tolerances *can be held on magnesium castings than on many other metals in both green and dry sand molds.*

Engineering Forms

Magnesium is fabricated by virtually all methods used on other metals excepting wire drawing. However, in choosing a method of fabrication, the inherent characteristics of the metal must be considered. The configuration of a part previously made in another metal should be modified to provide optimum draft, tapers, etc.; such changes can often make a difficult or impossible part into a feasible production item.

Castings

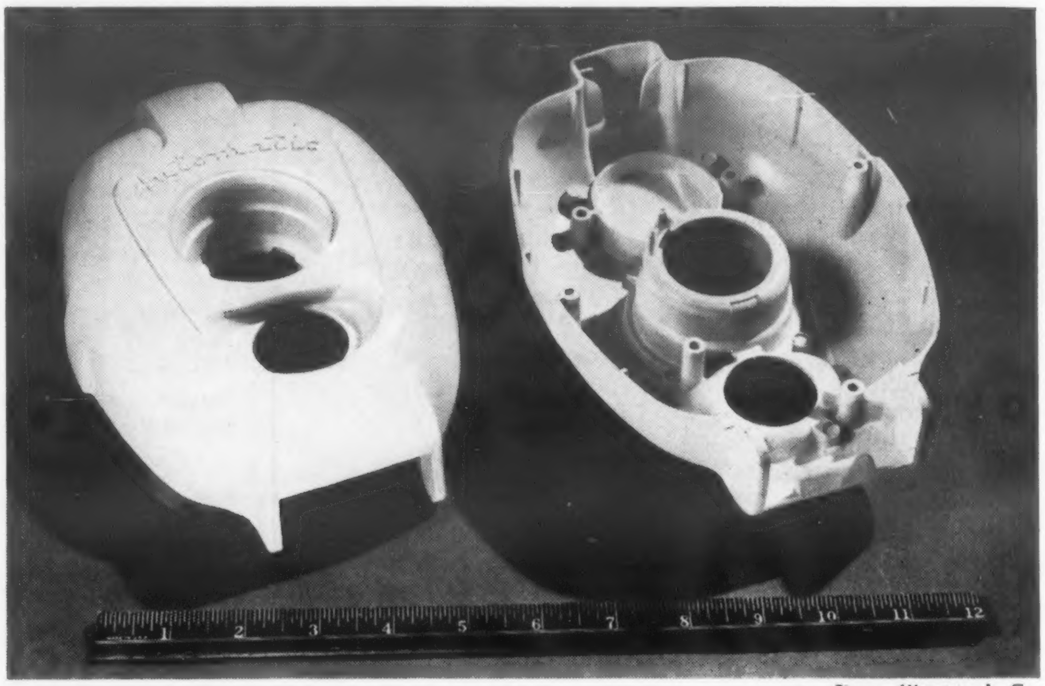
Probably the earliest form of magnesium alloys for structural applications was sand castings. Many of the alloys have excellent castability, and sections as thin as 1/10 in. are feasible. Excellent dimensional tolerances can be held; it appears that magnesium castings can be held to closer tolerances in both green and dry sand than many other metals.

Magnesium alloys have been cast in permanent molds for years, and use of permanent mold castings is expanding rapidly. More recently, equipment has been developed for hot chamber die casting, and this process promises to open a whole new area for magnesium.

Selection of a casting method

Magnesium castings are used for . . .


Aluminum Co. of America
Sewing machine parts. *Complex parts for featherweight model are made by sand casting.*


Dow Chemical Co.
Vacuum sweeper covers. *These parts are made by the hot chamber die casting process.*


Eclipse-Pioneer Div., Bendix Aviation Corp.
Gun turret parts. *This sand cast gimbal frame casting is being deburred.*


Aluminum Co. of America
Airplane engine parts *like this rear exhaust valve rocker cover.*

for producing magnesium parts represents a compromise among configuration, property requirements, surface finish, equipment costs, and the anticipated production quantity. Intricate, cored parts can usually be made best by sand casting, at a minimum investment in patterns and molding equipment. The increased cost of permanent mold equipment can often be justified for as few as 1000 parts in magnesium; properties of permanent mold castings are essentially equivalent to those obtainable in sand castings. Die castings offer advantages over sand and permanent mold castings

of improved dimensional control and surface finish, but longer production runs are required to justify the additional investment in equipment.

Generally speaking, control of molding sand compositions must be more meticulous for magnesium than for other metals, whereas the maintenance of steel permanent molds and dies is much simpler than for other metals. This often makes it economical to produce magnesium permanent mold or die castings on shorter runs than would be the case in aluminum, for example. The thinner sections obtainable by die casting often permit important savings in weight as well.

Nominal tolerance on dimensions of magnesium sand castings is 1/32 in., but some castings cannot be held to this limit economically. Some foundries have been able to approach ±0.010 in. per inch of casting length, with wall thickness held to ±0.010 in., but the additional expense of holding such tolerances on production items is seldom justifiable. In these respects magnesium is no different from other metals, although the lower pouring temperature often means easier control.

The unhindered solid state shrinkage of magnesium alloys is about 11/64 in. per ft. Shrinkage as low as ⅛ in. per ft is sometimes observed in large castings or where cores offer restraint. Pattern adjustments should be made to compensate for these differences.

Casting design should avoid configurations leading to local stress concentrations, particularly in regions subject to high stress or cyclic loading. Radii and fillets should be generous, changes in section size should be as gradual as possible, and notches and sharp corners should be avoided. Necessary markings, whether cast-in or stamped, should be on 1/16 to 3/32-in. raised pads located in regions that are not highly stressed in service.

Because of the rapid solidification in die castings, their mechanical properties are generally superior to those obtained by other casting methods. Additional improvement in strength results from the thin sections obtainable. Minimum section thicknesses below 0.050 in. are possible, with tolerances as low as ±0.003 in. In spite of their improved strength, die castings have been used most frequently in moderately or lightly stressed applications where excellent dimensional control and surface finish were desired.

Forgings

The forging of magnesium is a well developed art, and large forgings are practical. Most wrought alloys can be forged but the applications are usually confined to the higher strength magnesium alloys containing aluminum or aluminum and zinc. Recently, work has also been done on the alloys containing zirconium and zinc.

Hydraulic presses are preferred for forging magnesium because of their lower speeds, better control and greater flexibility. The M1 and AZ31B alloys can be hammer forged, and a 1200-lb steam hammer is roughly equivalent to a 500-ton hydraulic press. However, the stronger alloys are forged more successfully at the slower speeds obtained in presses.

Hot working die steels of the medium carbon, tungsten-chromium-vanadium types are recommended because the dies operate at 500 to 900 F. Press forging dies show little wear, but surface cracking may limit life to from 2000 to 20,000 operations. Dies should be heat treated to 300 to 400 Brinell hardness.

Forging stock is available as cast ingot or extruded billet, the latter offering better grain size control, finer structure and more uniform properties because of the preliminary working it has received.

Forging requires lubrication. The best lubricant is colloidal graphite applied to the hot dies as a suspension in a not-too-volatile carrier. The lubricant must be completely removed from the finished forging, because graphite and magnesium can form an electrocouple in an electrolyte (such as that resulting from condensation on the surface of cold forgings, for example), causing galvanic corrosion of the magnesium.

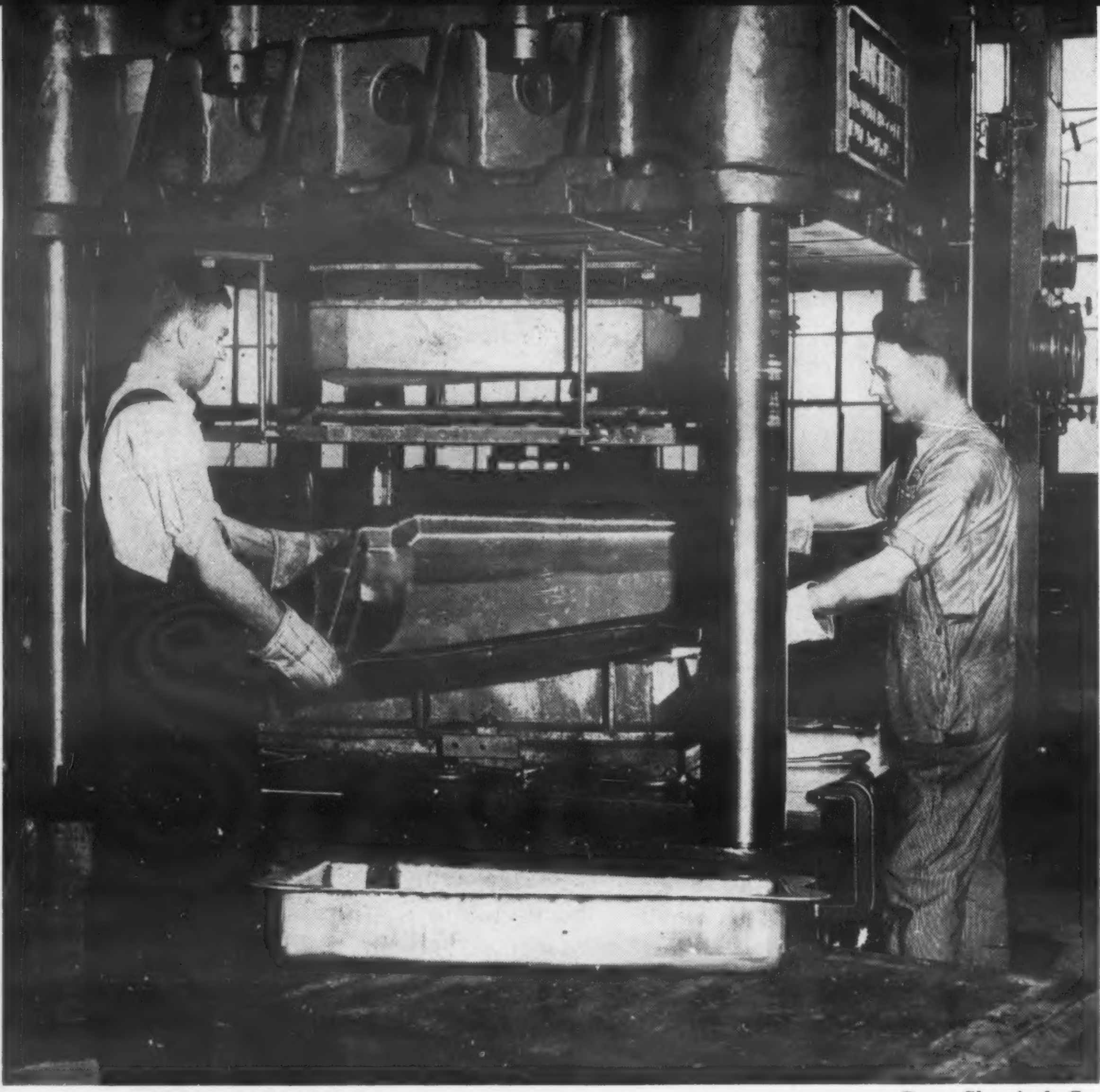
Forging stock is preheated to 650 to 750 F. Extruded billet requires only time enough to reach temperature. Cast ingot stock may require additional time at temperature, particularly in the case of the stronger alloys. In cases where hot shortness is indicated by surface cracking, heating for periods up to 6 hr at 750 F may improve forging characteristics.

Forging dies should have generous radii on reentrant angles to avoid cold shuts. Such defects cannot be expected to weld in magnesium as they may in steel, because the oxide film, even though much thinner, is much more refractory. When several forging steps are required with intermediate reheating, the temperature of each should be at least 50 °F lower than the preceding one and the reductions should be designed to provide a minimum of 20% reduction in the last operation. These precautions are necessary to avoid abnormal grain growth and resultant poor properties.

Extrusions

Most magnesium alloys show good extrudability and, generally speaking, strengths of the alloys at extrusion temperatures are low enough to permit very high reductions. Solid sections, tubing, and sections ribbed both inside and out are practical. Recent developments have permitted the extrusion of circular or other forms that can be cut longitudinally and straightened into complex shapes with rather large transverse dimensions. Such techniques permit the production of integrally stiffened flat structural members for use as stressed skins.

Extrusions and tubing can be bent by conventional methods. The softer alloys may be bent cold to large radii, but bending at elevated temperatures is required for severe bends on soft alloys and for the stronger alloys. Dies, methods of heating dies and



Dow Chemical Co.

Deep drawn parts *can be produced at moderately elevated temperatures.*

blanks, selection of temperatures, and lubricants are generally similar to those used in other methods.

Formed shapes

Those familiar with forming low carbon steel or low strength aluminum might consider magnesium alloys extremely difficult to form, and it is true that cold forming of magnesium must be confined to relatively small deformations. Nevertheless, when magnesium's excellent formability at relatively low temperatures is recognized and exploited, forming operations are often much simpler than for other metals. Temperatures required for hot forming are low enough to permit ordinary steel or cast iron tools to be operated at the necessary stress levels and temperatures indefinitely. It is often possible to perform in a single operation at 500 F, for example, a severe deep draw that would require several steps, with intermediate anneals, in other materials.

The limited cold formability of magnesium is a result of its hexagonal crystal structure and the limited available slip systems. Experimental alloys containing more than about 11% lithium have a cubic crystal structure and are as formable as low strength copper or aluminum alloys. However, these lithium alloys have relatively low strength unless they contain substantial additions of other elements, and these modified alloys over-age to low strength levels at relatively low temperatures. Nevertheless, there is growing interest in their possible short time applications in rockets or missiles.

Whereas at room temperature the magnesium hexagonal crystal can deform by slip only on the basal plane, at 400 F other crystal planes become active in slip, improving formability markedly. In addition, the strength of magnesium decreases with temperature, reducing the required equipment and tool capacities. Higher temperatures also reduce springback.

Though forming at elevated temperatures minimizes or eliminates the need for intermediate or final stress relief heat treatments, care must be exercised to avoid serious reduction of mechanical properties. Unlike most metals, magnesium sheet that has been strain or precipitation hardened can be formed at elevated temperatures, but prolonged exposure at these temperatures results in a deterioration of strength. By limiting the time of exposure, reduction in properties can be avoided. As shown in Table 7, the time-temperature limitations are not particularly restrictive. Techniques for heating and forming within these limitations have been worked out and offer no serious problems.

Proper production techniques in hot forming magnesium as many fabricators have found, offer real advantages, including: 1) deeper single draws, 2) reduced tooling costs through one-stage operation and use of low cost mild steel or cast iron dies, 3) reduced springback, 4) less wrinkling, and 5) adjustment of dimensions by changes in temperature.

Most formable of the alloys is M1, followed by AZ31A and the higher strength alloys. M1 and AZ31A in the O or F condition will undergo a limited amount of forming at room temperature, but elevated temperatures are required for more severe forming. Formability at a given elevated temperature depends on the temper or degree of strain hardening

TABLE 7—TIME-TEMPERATURE LIMITATIONS IN FORMING

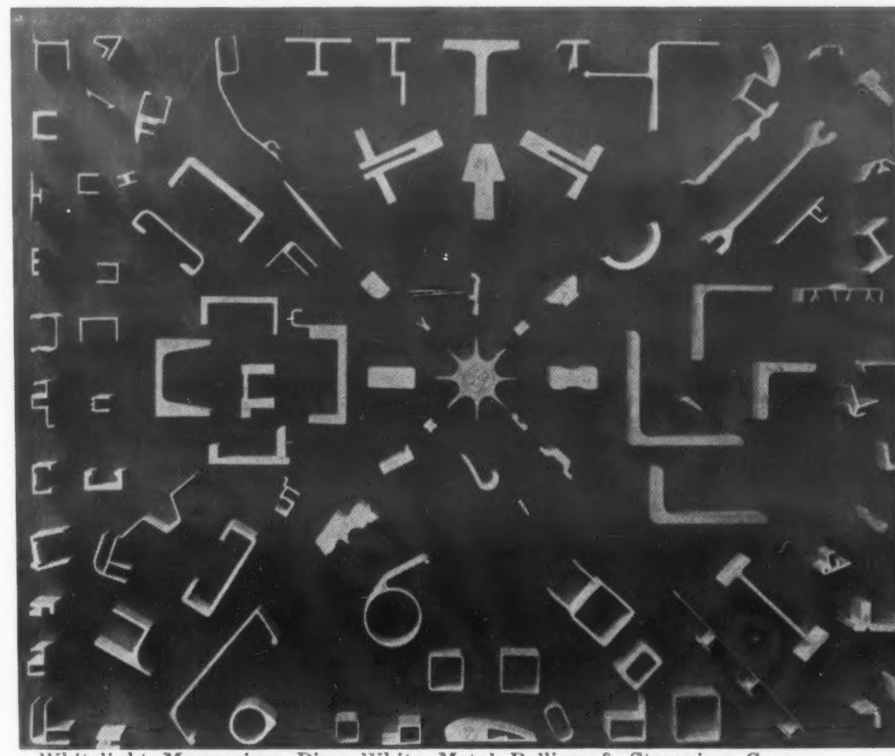
Alloy	Max Temp, F	Max Time, hr
SHEET		
AZ31-O	550	1
AZ31-H24	325	1
HK31-T6	600	1[a]
EXTRUSIONS		
AZ61A-F	550	1
AZ31B-F	550	1
M1B-F	700	1
AZ80A-F	550	½
AZ80A-T5	380	1
ZK60A-F	550	½
ZK60A-T5	400	½

[a]Preliminary data.

Magnesium extrusions are used for . . .

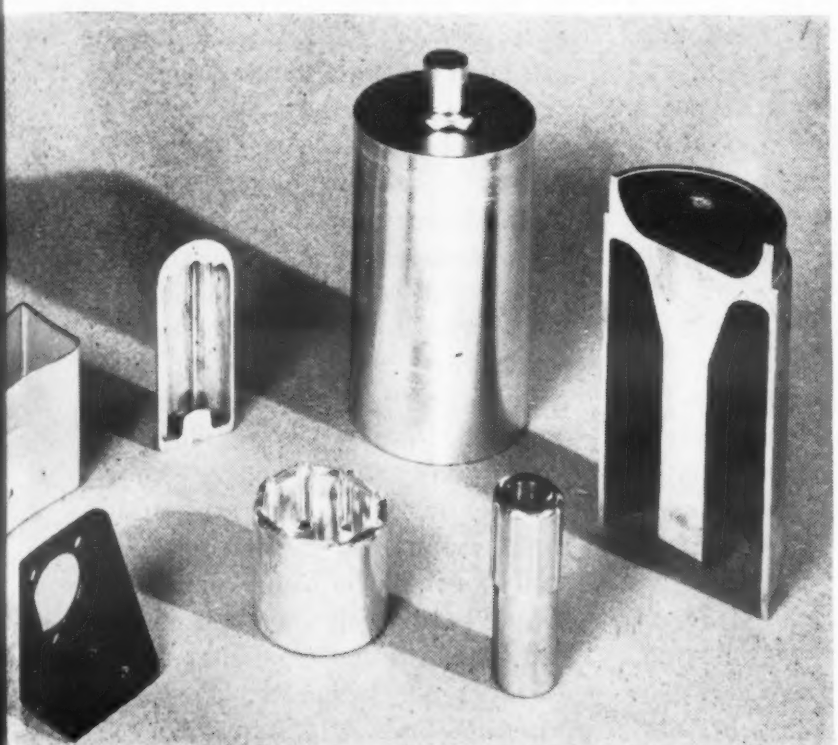
Dow Chemical Co.

Truck !oading ramps. *Magnesium's light weight increases the portability of these ramps.*



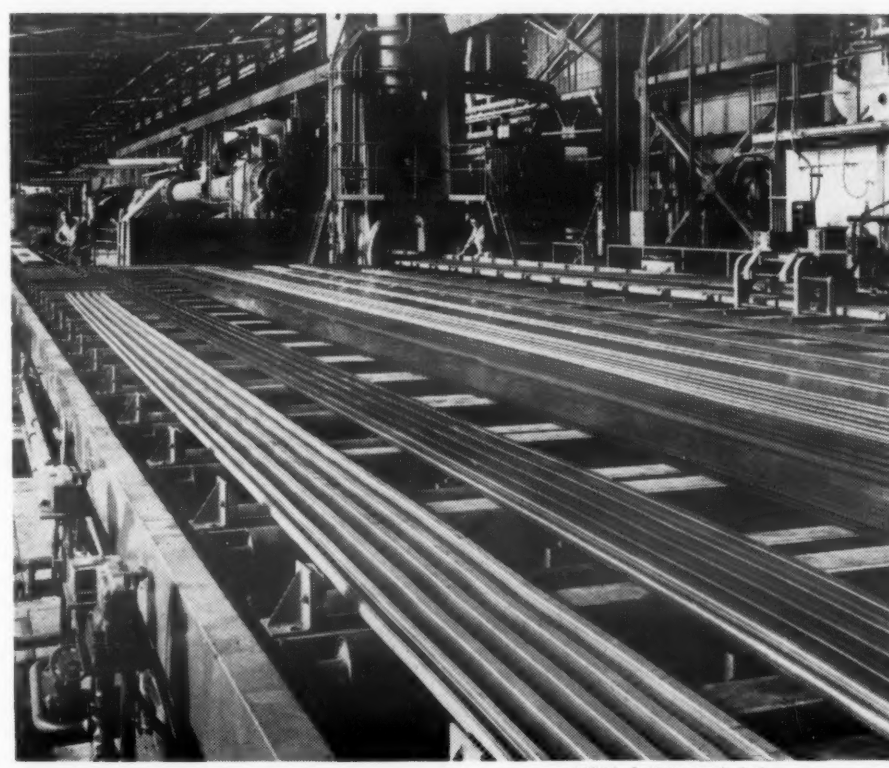
Whitelight Magnesium Div., White Metal Rolling & Stamping Co.

Parts of intricate cross section.



Dow Chemical Co.

Complex hollow parts. *Impact extrusion is used to produce no-draft parts of various contours.*



Dow Chemical Co.

Landing mats. *These landing mat sections are typical of the large integrally stiffened extrusions now produced from magnesium.*

of the sheet. Maximum formability will usually be found in the O or fully annealed condition.

Press forming — Most press forming techniques can be adapted for magnesium. Some general rules to follow are:

1. Form hot, maintaining uniform die temperatures.
2. Use relatively low speeds, decreasing speed for the more difficult operations.
3. Use annealed stock for the more severe forming operations, particularly cold forming.
4. Allow generous bend and corner radii.
5. Lubricate carefully with stable and highly effective lubricants.

Hydraulic presses are preferred for deep draws because they provide better control of speeds. Mechanical presses offer the advantage of greater production rates and can often be used when depth of draw is not great and when

more generous radii are permissible. Press capacity in tons can be approximated by the formula:

$$\text{Max pressure} = \frac{C\,t\,f}{2000}$$

where C = approx circumference of part, in.
t = thickness, in.
f = tensile strength of alloy at forming temperature, psi

In designing dies for forming magnesium, allowance must be made for the difference in thermal expansion between magnesium and the die materials. For example, in the range from room temperature to 600 F magnesium expands about 0.2% more than aluminum and 0.4% more than steel. Thus, dies for magnesium must be made oversize to achieve desired room temperature dimensions. Of course, uniform die temperatures are mandatory for close dimensional control.

Lubrication during drawing is necessary. For cold forming, most of the usual drawing compounds are adequate. For the usual hot drawing operations, the only satisfactory lubricant currently available is colloidal graphite.

Rubber pad forming—Trapped rubber forming has been applied to a limited extent to magnesium and offers the usual advantages of lower die costs. The limited cold formability of magnesium alloys has restricted this operation to relatively simple parts; however, the technique has been used at temperatures up to 550 or 600 F. Good results have been achieved with specially compounded rubbers (Durometer hardness about 40) in 1-in. layers cemented together to make pads up to 6 in. thick. Solid rubber blocks having 60-70 Durometer hardness work well for hot forming. Some fabricators, however, consider rubber life too short for many hot forming operations, and the choice of method must represent a compromise between die cost, number of parts to be made, and life of the rubber pad.

Selection of materials for, and design of, form blocks require a similar compromise. Wood, plastics, plaster or various metals are used depending on strength requirements and forming temperatures. Magnesium blocks have proved excellent up to 450 F.

Rubber pad pressures of about 900 psi suffice for most operations. Selection of temperature requires a compromise between forming difficulty and the mechanical properties desired in the part.

Bending—Cylindrical parts are readily formed in ordinary bending rolls. Magnesium alloys are also bent in both leaf and press type brakes, but the press type is preferred because the leaf type concentrates deformation at the clamping edge and promotes cracking. Also, dies are more easily heated in the press type.

Polished metal dies should always be used in bending. Press brake dies are usually heated with electric resistance strip heaters and preferably are insulated from the press to prevent heat loss. When heavier gage sheet and plate are bent, dies can be cold, but usually both dies and blank are heated.

Drop hammer forming — Although forming rates are quite high, drop hammer forming can be used on magnesium alloys in parts with shallow draws. The method is recommended only for AZ31-0, although hard rolled sheet can be formed into simple shapes that require a maximum compression of 5% and a maximum stretch of 10%.

Dies used for aluminum forming are suitable for magnesium. Kirksite has been used for production runs of 500 parts at temperatures up to 450 F. For longer runs cast iron dies can be used. Methods of heating dies, sheets and parts, and methods of lubrication are similar to those used with other forming methods.

Spinning—Magnesium sheet can be spun cold or hot, the selection of temperature being subject to the same limits as for other methods. The technique is similar to that used on other metals, although the rate of deformation should ordinarily be somewhat lower.

Stretch forming—Stretch forming has been recently applied to magnesium with the advantages found for other metals: even distribution of residual stresses, more uniform properties in the formed part, and more uniform section thickness. The method has been applied with equal advantage to sheet and extrusions. A limited amount of forming at room temperature is possible, but elevated temperatures are generally used.

Hand forming—Hand forming is often employed where small numbers of parts are required. Soft-jawed vises, wooden or metal forms, and soft hammers are used. Metal blocks or forms can be heated in several ways, and blanks can be heated in ovens or by torch. Temperature must be controlled carefully by contact pyrometers or temperature indicating pencils or lacquers. Although the need for elevated temperatures makes the technique somewhat more difficult than room temperature hand forming, an experienced operator can make quite difficult parts by this method.

Impact extrusions

Experience in this field has been quite limited to date, and the commercial availability of such extrusions has not been clearly defined. However, magnesium and many magnesium alloys can be impact extruded at reasonably high production rates into such parts as thick-bottomed cans, odd-shape cans with one end closed, and other symmetrical shapes that do not lend themselves readily to other methods of fabrication.

Hollow parts with various symmetrical section shapes and varying bottom thickness can be made at high production rates by impact extrusion. Length-to-diameter ratios may be as high as 15 to 1, with 8 to 1 considered typical. With careful alignment of press and tools, wall thickness tolerances can be maintained at ±5 to 10% of the thickness dimension in the range between 0.02 and 0.1-in. wall thickness.

Like other methods of forming magnesium, impact extrusion is

performed hot, but production rates of 100 parts per min are possible. Automatic feeding mechanisms that also preheat the slugs are favored for high production operations.

Punches are hardened tool steel. Dies of steel or carbide have expected lives of 200,000 and 10,000,000 parts respectively. Punches and dies are maintained at temperatures between 350 and 700 F, depending on the magnesium alloy and the desired part configuration. Heat supplied by the preheated magnesium slugs is usually sufficient to maintain die temperatures, but in some slower, hand feed operations additional heat may be necessary.

Press capacity requirements depend on amount of reduction, alloy, temperature, part configuration and, to some degree, speed. A simple 1-in. cylinder with 0.020-in. wall requires about 24,000 psi in pure magnesium and about 42,000 psi in AZ80A at 500 F. At a reduction in area of 85%, pressure requirements decrease about 3000 psi per 100° F temperature increase for AZ80A, and about 6000 psi per 100° F for AZ31B or M1.

Processing Characteristics

Machining

Magnesium is probably the easiest of all metals to machine. Relatively low resistance to cutting is accompanied by a natural free-machining quality that permits surface speeds and metal removal rates as high as can be obtained on modern machine tools.

The heavier depths of cut and higher rates of feed permissible with magnesium require that tools be designed with maximum chip clearance. Lower tool loads and work of cutting, compared with other metals, permits greater relief angles and chip clearance. Only by designing tools specifically for magnesium can the fullest

How to Avoid Magnesium Fires

As the engineering use of magnesium has grown, the spectre of fire in shops melting and fabricating the metal has gradually assumed more realistic proportions. It is true that finely divided magnesium will ignite and sustain combustion, and that magnesium fires cannot be controlled or stopped by common techniques. Nevertheless, when simple rules are observed, magnesium offers no special fire hazards.

Ignition point

Magnesium will ignite only at temperatures very near the melting point, 1200 F. Very finely divided magnesium powder can ignite at air temperatures as low as 900 F, probably because some particles oxidize fast enough to raise the temperature locally. Some alloys may ignite at temperatures as low as 800 F, but this temperature is several hundred degrees above the ignition point of wood. It is extremely unlikely that any accidental generation of heat, excepting a large general fire, could ignite massive magnesium, such as ingot or heavy extrusions, because the rate at which heat is conducted and dissipated by magnesium is so high that only massive heat sources can raise the temperature to the ignition point. Even magnesium sheet is difficult to ignite and requires a concentrated source such as an oxyacetylene torch applied to an edge. When ignited, the sheet usually burns quietly and progressively and may extinguish itself.

Ponder a problem

Nevertheless accumulations of fine powder or chips can be dangerous. A match flame is hot enough to ignite such materials under ideal conditions, and the fire can be self-sustaining. Machining operations should be adjusted to generate the thickest chip consistent with the desired finish. Chips should not be permitted to accumulate, should be stored in covered containers, and should be kept dry to prevent the accumulation of hydrogen resulting from reaction between water and finely divided magnesium.

Collect dust

Grinding operations should be done wet and the dust collected in a good tight system. The system must be adequately vented to prevent the accumulation of hydrogen resulting from the magnesium-water reaction.

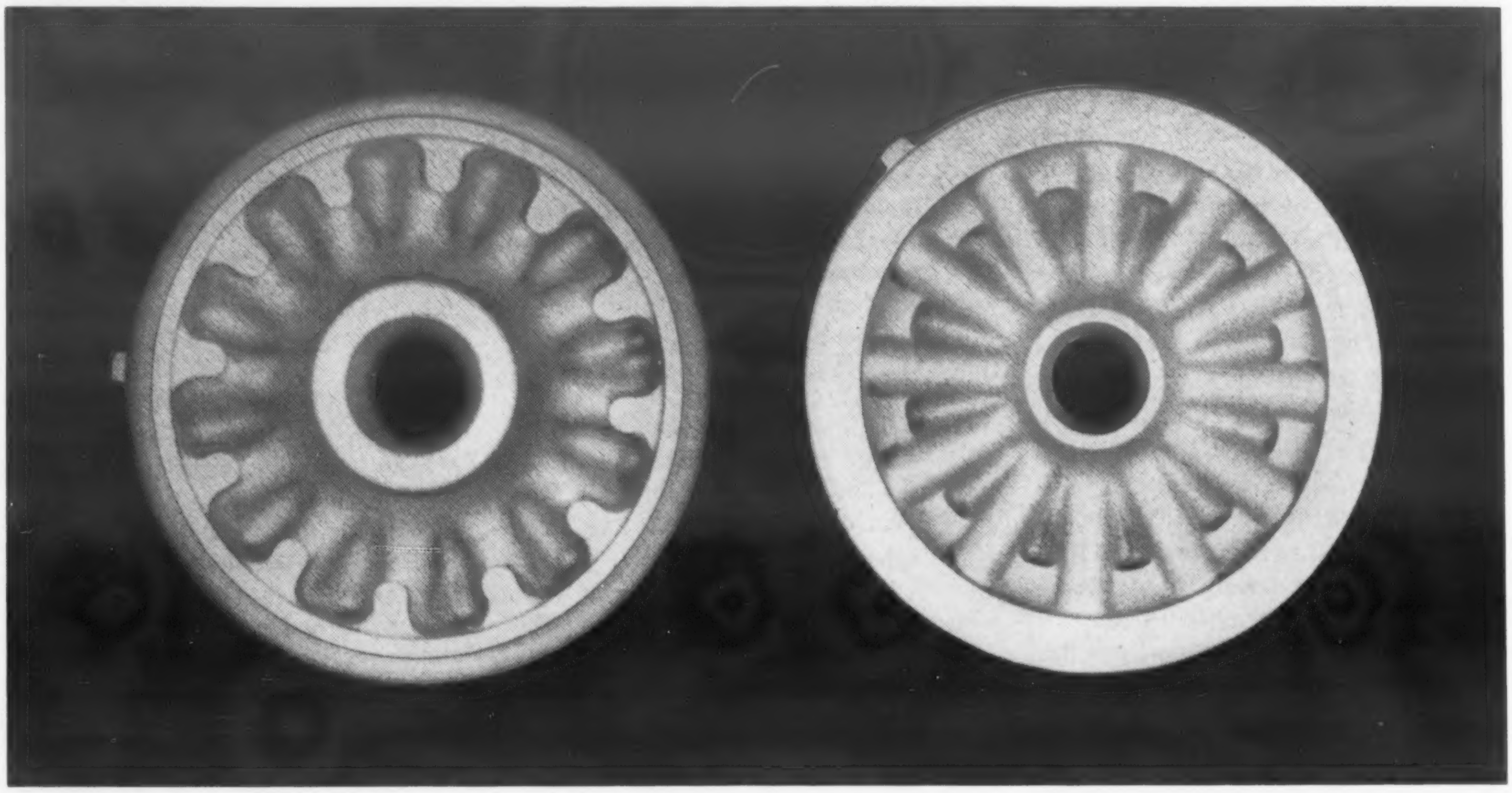
Operations that may generate incidental fine powders should be policed to prevent accumulation of fines that would propagate a fire once ignited. Machining operations, even though they are well controlled, may generate some amount of airborne fines. Over a period of months or years this dust may accumulate to a dangerous degree if not recovered periodically.

Safe practices for processing, handling, and storing magnesium and of disposing of scrap are detailed in NFPA No. 48, Standards for Magnesium, approved and published by the National Fire Protection Assn. The Magnesium Assn. has condensed the recommendations into a shop card for ready reference.

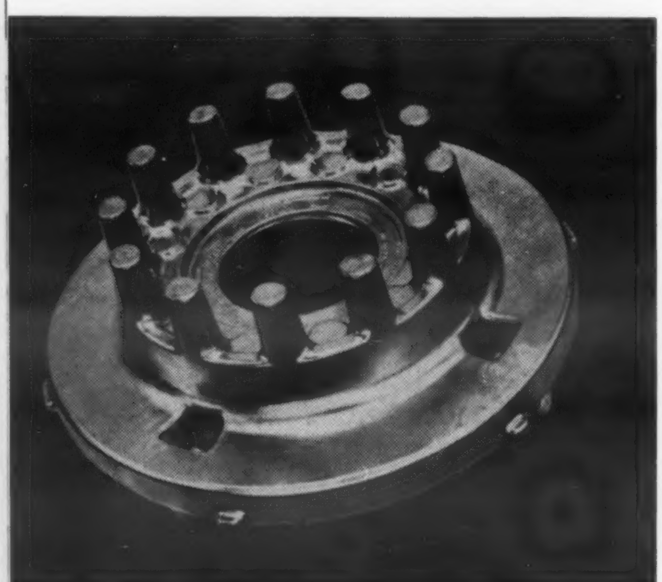
Stopping a fire

Once a fire is started, only a few alternatives are available. Burning magnesium will react exothermically with almost all chemicals used for extinguishing fires, including water and carbon dioxide. The only method of controlling magnesium fires is by excluding air, i.e., smothering the fire with a material that will not accelerate the oxidation of the burning magnesium. Large amounts of sand, preferably dry, will work. Foundry fluxes will control fires, but they must be kept dry. The most effective composition is a mixture of powdered graphite with some heavy hydrocarbons, prepared and sold as "G-1" powder. It is effective on all metal fires and should be available near foundry and machine shop operations where the possibility of fire exists.

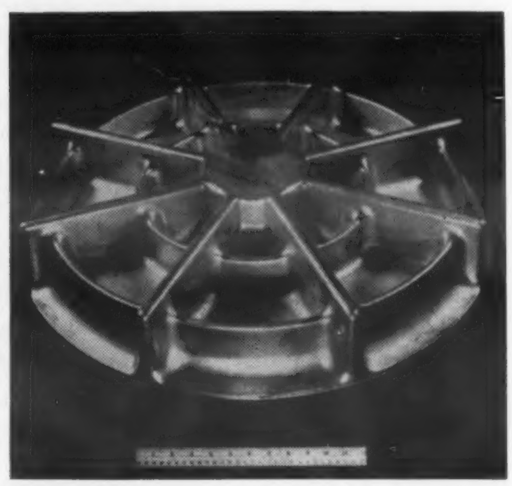
Magnesium forgings are used for . . .



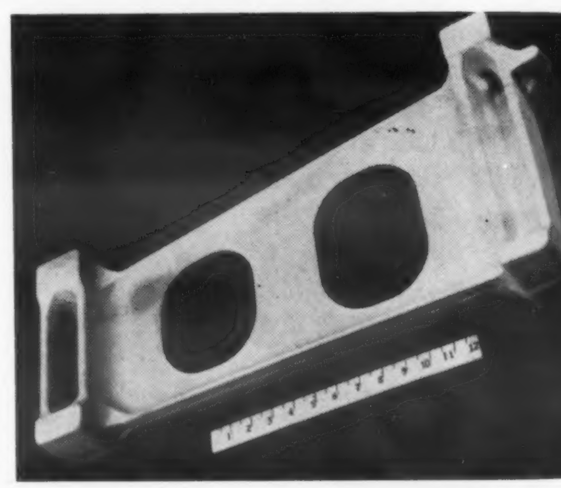
Aircraft landing wheels. *Most of the wrought alloy compositions can be forged.*



Landing gear brake carriers.



Mortar base plates. *These plates, forged from 58S magnesium alloy, weigh 105 lb and have an area of 707 sq in.*



Aircraft wing parts. *This external storage wing adapter is produced from AZ80X magnesium alloy.*

All photos courtesy Wyman-Gordon Co.

advantage be taken of magnesium's excellent machinability.

Nevertheless the requirements are not stringent. Tool life is outstanding, although sharp tools are mandatory. Unparalleled surface finish is possible without undue care, and power requirements are lowest of any metal. Because magnesium alloys are easily scratched or nicked by steel tools, and because they are quite susceptible to failure resulting from stress concentrations induced by surface flaws, particular care should be exercised to avoid such damage.

Heat treatment

The heat treatment of magnesium alloys is similar to that of aluminum alloys. It consists essentially of a solution heat treatment near the solidus temperature of the alloy, normally in the range 750 to 1050 F but depending upon the composition. Magnesium alloys usually do not require rapid quenching after solution treatment, an advantage in avoiding residual stress created by quenching operations. Solution treatment may be as long as 24 hr for castings and as short as 2 hr for

wrought products. Aging temperatures vary between about 350 and 500 F, depending upon the composition. Aging times are usually considerably longer than those used for aluminum; they may vary between 24 and 48 hr in many magnesium alloys.

Maximum heat treatment response is afforded by zinc additions over about 2%. Aluminum additions offer little aging or heat treatment response. Some of the newer alloys containing thorium and zirconium show considerable heat treatment response, but this is usually a result of the presence of zinc.

Joining

Most metal joining methods have been adapted for use with magnesium. Mechanical fasteners such as rivets or bolts have been used longest. Welding, particularly shielded arc and resistance welding, is of growing importance. Adhesive bonding has particular advantages that will probably assure its use to an increasing degree.

Fastening—Rivets and bolts can be used to join magnesium to other metals, whereas welding cannot. Riveted joints can be made with excellent and predictable joint efficiency, using simple procedures and semiskilled labor.

Magnesium is commonly joined with aluminum rivets. Aluminum alloys 5056, 6053 and 6061 provide joint strengths in the ranges desired for magnesium alloys, and the electropotential between magnesium and these aluminum alloys is not excessive. Recommended edge distance is a minimum of 2.5 times the rivet diameter (center of the hole), and rivet spacing a minimum of 3 times the diameter.

Magnesium sheet up to 0.050 in. thick can be dimpled usually hot for flush riveting. Heavier gages may be countersunk, but the countersink must not approach closer to the opposite surface of the sheet than 0.015 in.

Welding—All forms of welding have been used on magnesium. Gas welding, however, is used only for repair work because the necessary fluxes can create a corrosion problem if not completely removed.

The inert-gas-shielded arc welding process is applied to magnesium with excellent results. Butt and fillet joints are most adaptable to this process, and joint efficiencies of more than 90% of the strength of annealed parent metal are common. The method is applicable to sheet as thin as 0.040 in., and there appears to be no practical upper limit on thickness.

Many production and assembly operations use the tungsten electrode with or without filler wire. The consumable electrode method is particularly suited to automatic welding operations and provides excellent weld strength, particularly in heavy sections.

Spot welding is the most common form of resistance welding applied to magnesium. High quality welds can be assured by proper cleaning of the surfaces and by close control of the welding cycle. Because of their relatively poor fatigue resistance, spot welds are seldom used in stressed assemblies.

Adhesive bonding — Adhesive-bonded joints provide excellent resistance to fatigue, can be used with very thin sheet, and need no special insulator between dissimilar metals. Adhesive bonding can provide smoother surfaces than other joining methods, as well as important cost savings. The technique is applicable only to lap joints where the only significant loads are shear loads. Joining is accomplished by heat and applied

Sheet and extrusions *can be built into various structures by inert-gas-shielded arc welding.*

Dow Chemical Co.

pressure, and joints must be designed with this in mind. The temperature required for curing, however, is not high enough to affect the properties of the base metal and joint efficiencies of 100% are possible if the bonding area is sufficiently large.

Effective bonding requires not only uniform application of the adhesive but meticulous precleaning of the metal surfaces. Low strength joints can be made after priming or anodizing. Maximum strength, however, is obtained on bare metal after alkaline cleaning and mechanical polishing. A number of adhesives known to meet Air Force specifications, including 1) phenol-formaldehyde plus polyvinyl formal, 2) phenolic rubber-base resin and 3) a phenolic synthetic rubber plus a thermosetting plastic, can provide shear strengths over 2000 psi under certain conditions.

Finishes and Finishing

Uncoated magnesium alloys have shown resistance to deterioration in ordinary urban or rural atmospheres superior to that of many common structural metals. The light gray film that develops in normal inland atmospheres is not generally objectionable on industrial equipment such as truck bodies or foundry flasks. However, a more attractive surface may be desired for sales appeal and customer satisfaction, and conversion coatings, paint systems or electroplates can be used.

Surface preparation of magnesium is necessary before metal forming operations and before various finishing operations.

Beware of Electrolytic Couples

These methods of finishing magnesium provide surfaces with excellent appearance and resistance to corrosive environments. Normally, however, magnesium is fastened to other metals. Since magnesium is highest of all structural metals in the corrosion potential series, adequate service life can be assured only if proper assembly procedures are used.

Electrical contact between magnesium and other metals should be eliminated by suitable insulation, and designs should not permit the accumulation of moisture either from weather or condensation. Insulating materials must remain nonconductive under service conditions, and therefore must not be porous or deteriorate with time. It is desirable to join magnesium with metals not too dissimilar in corrosion potential. Steel should be cadmium or zinc plated, and may advantageously be separated from the magnesium with aluminum to minimize any possible electropotentials. Protective finishes must cover the less active metal as well as the magnesium, because penetration of the coatings on the magnesium could result in catastrophic corrosion if a large cathode area were available in the form of uncoated steel.

In spite of the great deal of concern observed in the application of magnesium, many uses require no special protection whatsoever. Portable power tools and appliances combine magnesium, aluminum, steel and copper with no special precautions. Service experience has been excellent because no electrolyte is normally present.

Mechanical cleaning

Many metals scale freely during heating for forging, and a clean surface is obtained by removing this scale mechanically during or prior to the forming steps. (In some metals surface defects will be welded and healed in the forming operation but in magnesium such defects do not heal and dirt is often worked into the surface.)

Mechanical surface treatments include machining, sand or grit blasting, and wire brushing. Machining operations can be done dry and no subsequent treatments are required. Sand or grit blasting should be followed by pickling to remove enough metal (about 0.002 in.) to assure the removal of sand or grit imbedded in the surface.

Chemical cleaning

Acid pickling is required to remove previously applied chemical treatments, oxide tarnish when mechanical treatments are not used, and surface contamination that might impair corrosion resistance.

When appropriate, acid pickling can be preceded by solvent cleaning to remove heavy oil and grease deposits, and alkaline cleaning to remove grease or previously applied lubricants or chemical coatings. Conventional chlorinated solvents, petroleum spirits, naphtha and lacquer thinners work well as solvent cleaners. Alkaline cleaners may be heavy-duty types, as used on steel, and are usually operated at about 200 F for 3 to 10-min immersion. Removal of imbedded graphite lubricant is best effected by immersion (up to 20 min) in a solution containing 13 oz per gal of sodium hydroxide.

Solutions commonly used to pickle magnesium include:

Chromic-nitrate, most common in-process pickle.

Chromic acid	24 oz/gal
Sodium nitrate	4 oz/gal

Chromic - nitric - hydrofluoric for castings, particularly die castings.

Chromic acid	37½ oz/gal
Conc nitric acid (70%)	3¼ fl oz/gal
Hydrofluoric acid (60%)	1 fl oz/gal

Chromic acid to remove old chemical coatings without dimensional change.

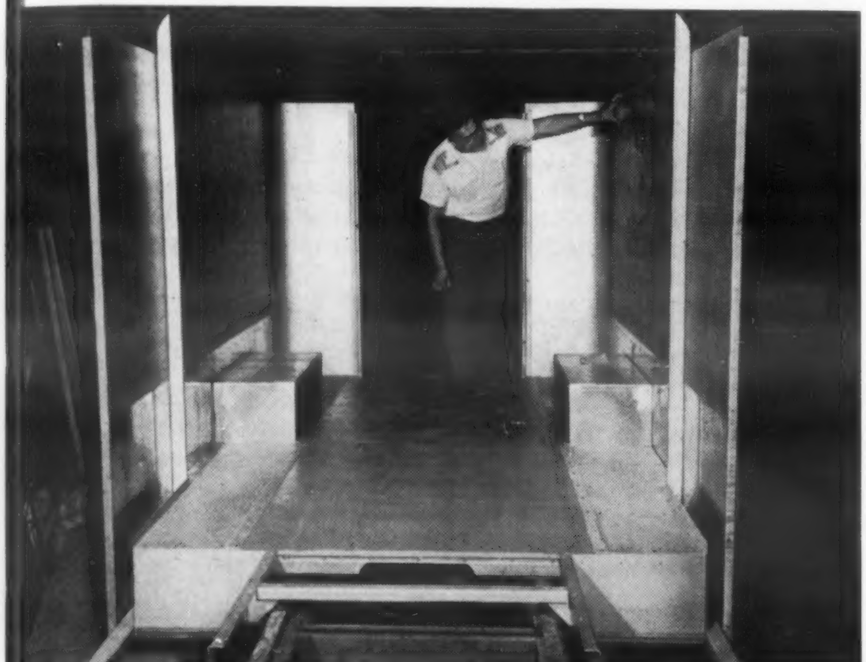
Sheet and plate of magnesium are used for . . .

Dow Chemical Co.

Tooling plates. *Among the latest applications for magnesium, these plates are used in the aircraft, automotive and electronics industries.*

Brooks & Perkins, Inc.

Earth satellite skins. *Skin being hot spun from magnesium will be machined to a thickness of 0.028 in.*



Dow Chemical Co.

Truck body walls. *Heavy gage magnesium sheet is used for these walls of monocoque design.*

Dow Chemical Co.

Airplane skins. *More than 25% of the skin of the Chance-Vought Crusader is composed of magnesium AZ31-B sheet.*

Chromic acid (CrO_3)	24 oz/gal

Chromic-sulfuric to clean for spot welding.

Chromic acid	24 oz/gal
Conc sulfuric acid	0.06 oz/gal

Sulfuric acid.

Conc sulfuric acid	4 fl oz/gal

Acetic-nitrate to prepare surface for protective finishes.

Glacial acetic acid	25½ fl oz/gal
Sodium nitrate	6⅔ oz/gal

Mechanical finishes

Parts can be finished by a number of mechanical finishing processes. Polishing and buffing produce bright surfaces that can be protected with clear baked lacquers. Mechanical tumbling and burnishing; grinding; and deburring, polishing and coloring can be done with procedures that are modifications of those used on other metals.

Conversion coatings

Conversion coatings are produced by a chemical reaction between the magnesium surface and a coating bath, sometimes modified by the use of electric current. Such coatings are used to provide better paint adherence, improved resistance to corrosive environments, and improved resistance to abrasion. Many such coatings have been developed by Dow

Chemical Co. and are often known by the Dow number; two electrochemical treatments, HAE and Cr-22, have been developed by Frankford Arsenal. (See Table 8).

Organic coatings

For maximum adherence and protection, paint systems should be applied only to magnesium surfaces that have been properly treated chemically. Commonly used treatments, in order of increasing effectiveness, are chrome pickle, dichromate, galvanic anodize, sealed chrome pickle, anodize, HAE and Cr-22. Paint systems consist of one or more coats of primer, pigmented with titanium dioxide or zinc chromate for improved protection, and one or more finish coats. The primer should be chosen for adherence, preferably to bare metal as well as to the chemical coatings. "Wash primers" effect adhesion by etching the metal surface, but must be used with caution because excessive reaction may blister the paint system. Generally speaking, primers developed for and used

TABLE 8—CHEMICAL TREATMENTS FOR MAGNESIUM

Treatment			Treatment May Be Used on . . .	Appearance	Uses	Remarks
Dow No.	Name	Type				
1	Chrome Pickle	Chemical	All alloys	Matte gray to yellow red	General purpose treatment applied to practically all forms of magnesium for protection during shipment and storage. Good paint base	Simple dip treatment, usually the cheapest to apply. Etching action causes slight dimensional loss
4	Chrome-Alum	Chemical	Die cast AZ91	Brown-black	Used only as a black decorative finish for die castings	Offers some improvement in adhesion of paint
7	Dichromate	Chemical	All aluminum-containing alloys, EK33 and ZK60. Cannot be used on M1, EK30 or EK41A	Brown	Provides best combination of paint-base and protective qualities	Does not materially affect dimensions. Requires ½ hr or more in boiling solution
8	Alkaline Dichromate	Chemical	All aluminum-containing alloys, EZ33 and ZK60. Cannot be used on M1, EK30 or EZ33	Brown-black	Used for black finish on all forms. More protective on die castings than No. 4	Has protective and paint-base qualities. Requires boiling in solution ½ hr or more
9	Galvanic Anodize	Electrochemical	All alloys	Black	Used on M1 in place of No. 7 or 8 and on any other nonaluminum-containing alloys not treatable in No. 7 or 8	Requires galvanic couple between work and steel tank or steel cathode plates if tank is ceramic-lined
10	Sealed Chrome Pickle	Chemical	All alloys	Similar to No. 1	Alternate for No. 7 when dimensional loss can be tolerated	Better protection than No. 1 due to boiling 30 min in dichromate solution
12	Caustic Anodize	Electrochemical	All alloys	Light shades of gray and tan	Specialty treatment combining decorative finish with abrasion resistance and protective value	Can be dyed. Neutralizing seal gives it paint-base qualities equal to No. 7 treatment
14	A-C Anodic	Electrochemical	All alloys	Light gray to white	Good abrasion resistance. Can be painted when given a neutralizing seal. Cannot be dyed	Will cover flow marks in die cast surface. Should be waxed to prevent smudging
15	Bright Finish for Wrought Products	Chemical	AZ31, AZ61, ZK60A, AZ80 and M1	Silvery	Decorative finish used only on wrought magnesium	Good "shelf life" appearance. Dimensions slightly affected by treatment
16	Bright Finish for Castings	Chemical	AZ92, AZ63, AZ91, EK30, EK41 and EZ33	Silvery	Decorative finish used only on magnesium castings	Appearance similar to No. 15, good "shelf life" appearance. Slight effect on dimensions
17	Anodize	Electrochemical	All alloys	Light to dark green	Protective and decorative finish	Most abrasion resistant, best paint-base and most consistently applied of all Dow chemical treatments for magnesium
18	Phosphate Touch Up	Chemical	All alloys	Medium to dark gray	Protective touch-up treatment	Less critical touch-up than No. 1. Good paint base
—	HAE	Electrochemical	All alloys	Light tan to brown	Protective and decorative finish	Excellent abrasion resistance in heavier thicknesses, excellent corrosion protection when properly sealed
—	Cr-22	Electrochemical	All alloys	Light green to black	Protective and decorative finish	Excellent corrosion resistance, especially when sealed, high hardness

Alloy Nomenclature and Temper Designation

Alloy nomenclature of magnesium-base alloys, which is based on chemical composition, is determined by the following rules in ASTM B 275-53T:

Alloy Nomenclature

1. Designations for alloys consist of not more than two letters representing the alloying elements[a] specified in the greatest amount, arranged in order of decreasing percentages, or in alphabetical order if of equal percentages, followed by the respective percentages rounded off to whole numbers and a serial letter[b c]. The full name of the base metal precedes the designation, but it is omitted for brevity when the base metal being referred to is obvious.

[a] For codification an alloying element is defined as an element (other than the base metal) having a minimum content greater than zero, either directly specified or computed in accordance with the percentages specified for other elements. The amount present is the mean of the range (or the minimum percentage if only that is specified) before rounding off.

[b] The serial letter is arbitrarily assigned in alphabetical sequence starting with A (omitting I and O) and serves to differentiate otherwise identical designations. A serial letter is necessary to complete each designation.

[c] The designation of a casting alloy in ingot form is derived from the composition specified for the corresponding alloy in the form of castings. Thus a casting ingot designation may consist of an alloy designation having one or more serial letters, one for each product composition; or it may consist of one or more alloy designations.

2. The letters used to represent alloying elements should be those listed in the table below:

A—Aluminum	G—Magnesium	P—Lead
B—Bismuth	H—Thorium	Q—Silver
C—Copper	K—Zirconium	R—Chromium
D—Cadmuim	L—Beryllium	S—Silicon
E—Rare Earths	M—Manganese	T—Tin
F—Iron	N—Nickel	Y—Antimony
		Z—Zinc

3. In rounding off percentages, the procedure described in Recommended Practices for Designating Significant Places in Specified Limiting Values (ASTM E 29) should be used.

4. When a range is specified for the alloying element, the rounded off mean should be used in the designation.

5. When only a minimum percentage is specified for the alloying element, the rounded off minimum percentage should be used in the designation.

Temper designation

The temper designation is separated from the alloy by a dash and is determined by the following set of rules from ASTM B 296-54T:

1. The designations for temper are based on the sequence of basic treatments used to produce the temper.

2. The temper designation, which is used for all metal forms except ingot, follows the alloy designation and is separated therefrom by a dash.

3. Basic temper designations consist of letters. Subdivisions of the basic tempers, where required, are indicated by one or more digits following the letter. These digits designate a specific sequence of basic treatments, but only those operations which are recognized as significantly influencing the characteristics of the product are indicated. Should some other variation of the same sequence of basic operations be applied to the same alloy, resulting in different characteristics, then additional digits are added to the designation.

4. The temper designations and the subdivisions are fully defined and explained below:

F—As Fabricated—This designation applies to products which acquire some temper qualities in the shaping processes but are not subsequently thermally treated or intentionally strain hardened.

O—Annealed Recrystallized (wrought products only)—This designation applies to the softest temper of wrought alloy products.

H—Strain Hardened—This designation applies to those products which have their strength increased by strain hardening with or without supplementary thermal treatments to produce partial softening. The -H is always followed by two or more digits. The first digit indicates the specific combination of basic operations, and the following digit or digits the final degree of strain hardening.

Subdivisions of the H temper

H1—Strain Hardened Only—The number following this designation indicates the degree of strain hardening.

H2—Strain Hardened, Then Partial Annealed—The number following this designation indicates the degree of strain hardening remaining after the product has been partial annealed. For alloys that age-soften at room temperature the -H2 tempers have approximately the same tensile strength as the corresponding -H3 tempers and slightly higher elongations. For other alloys the -H2 tempers have approximately the same tensile strength as the corresponding -H1 tempers and slightly higher elongations.

H3—Strain Hardened, Then Stabilized—The number following this designation indicates the degree of strain hardening remaining after the product has been strain

continued

successfully on other metals are not suitable for magnesium. On the other hand, primers developed for magnesium do adhere well to steel or aluminum.

Finish coats should be chosen for compatibility with the primer, and for ability to provide the necessary level of protection. Baked enamels provide rapid finishing, excellent adhesion, maximum impermeability and good serviceability. They may be applied to some chemically treated surfaces without a primer with good results. Novelty finishes, such as wrinkle, mother of pearl and hammered metal, can be applied to magnesium much as to other metals.

Clear finishes can be applied over buffed bare metal or chemical coatings, preserving the bright appearance of the surface. Only a few lacquers that are protective have good adhesion; vinyls and modified vinyls work well and their performance can generally be improved by baking.

Rubbers, both hard and soft, can be bonded to magnesium either by direct vulcanizing or by the use of special adhesives. Many rubber producers have developed techniques for bonding to produce such items as solid rubber-tired

continued

hardened a specific amount and then stabilized. This designation applies only to those alloys which, unless stabilized, age-soften at room temperature.

Subdivisions of the H1, H2, and H3 tempers

The number following these designations indicates the final degree of strain hardening. The numeral 8 designates the temper normally regarded and arbitrarily selected as "full hard." Material having a tensile stregnth about midway between that of fully annealed material (–0 temper) and that of the 8 temper is indicated by the numeral 4. The numeral 2 designates material having a tensile strength about midway between that of –0 temper and 4 temper, and 6 temper material is midway in strength between 4 temper and 8 temper. Although 8 temper is considered the "full hard" temper, a slightly harder temper, designated by the numeral 9, is produced for special applications.

W—Solution Heat Treated—This is an unstable temper, It is applicable only to those alloys which spontaneously age at room temperature after solution heat treatment. This designation is specific only when the period of natural aging is indicated.

T—Treated to Produce Stable Tempers Other Than F, O or H. Applies to products thermally treated to produce stable tempers with or without supplementary strain hardening. If strain hardening supplements the thermal treatment, it is considered in the temper designation only where it is recognized as materially influencing the characteristics of the product. The –T is always followed by one or more digits. The numerals 2 through 10 indicate types of treatment, each numeral designating a specific sequence of basic operations. When required, the numerals 11 through 19 are available for designating other types of treatment. The details of the treatment will usually be different for each alloy to produce certain desired results. The treatment usually considered standard is designated by –T followed by the numeral indicating that type of treatment. Deliberate variations of the conditions, resulting in significantly different characteristics for the product, are indicated by adding one or more digits to the treatment designation. No attempt is made to have these indicate any specific set of conditions. It should be understood that a period of natural aging at room temperature may occur between or after the operations listed. Control of this period is exercised when it is metallurgically important.

Subdivisions of the T temper

T2—Annealed (cast products only)—Applied to castings only to indicate a type of annealing operation used to improve ductility and increase dimensional stability.

T3—Solution Heat Treated, Then Cold Worked—Applies to those products where cold work is performed for the primary purpose of improving the strength, and also applies to those products in which the effect of cold work (such as flattening or straightening) is recognized in applicable specifications.

T4—Solution Heat Treated and Naturally Aged to a Substantially Stable Condition—Applies when the product is not cold worked after heat treatment, and also when applicable specifications do not recognize the effect of cold work in flattening and straightening operations.

T5—Artificially Aged Only—Applies to products which are artificially aged without prior solution heat treatment. The artificial aging of these products may improve mechanical properties and/or dimensional stability.

T6—Solution Heat Treated, Then Artificially Aged—Applies to products which are not cold worked after solution heat treatment, and in which the effect, if any, of flattening or straightening is not recognized in applicable specifications.

T7—Solution Heat Treated, Then Stabilized—Applies to products in which the temperature and time conditions for stabilizing are such that the alloy is carried beyond the point of maximum hardness, providing control of growth and/or residual stress.

T8—Solution Heat Treated, Cold Worked, Then Artificially Aged—Applies when the cold working is done for the purpose of improving strength, and also when the cold working effect of flattening or straightening is recognized in applicable specifications.

T9—Solution Heat Treated, Artificially Aged, Then Cold Worked—Applies when the cold working is done for the purpose of improving strength.

T10—Artificially Aged, Then Cold Worked—Applies to products which are artificially aged without prior solution heat treatment and then cold worked for the purpose of improving strength.

wheels, rubber-covered typewriter platens and rubber-coated control handles.

Plating

Methods for electroplating magnesium have been reduced to commercial practice over the past several years. Procedures differ from those used on other metals because the chemical reactivity of magnesium is too high for successful plating directly on the magnesium. A part must first be activated, after thorough cleaning, in a phosphoric acid-fluoride bath. The part is then immersed in a buffered solution of zinc sulfate until the reaction precipitates a thin film of zinc over the surface. A copper strike is applied over the zinc using a conventional cyanide bath. Conventional techniques for subsequently applying copper, nickel, cadmium, zinc, brass, silver and chromium are modified for use on magnesium only in minor details, which reflect the need to avoid dissolving the thin copper or zinc, or attacking the base magnesium before the plate builds up. For this reason alkaline baths are used when possible, and pH kept as high as practicable in acid solutions.

Acknowledgments

This manual was prepared from information largely made available by members of the Magnesium Assn. Their assistance, individually and collectively, is gratefully acknowledged. P. D. Frost and C. H. Lorig of Battelle are thanked for their review and constructive criticism. The manuscript was prepared with assistance of the Battelle staff.

Reprints of this Manual are available at 35¢ each until supply is exhausted. See page 174 for complete list of available Manuals. Write for quotations on quantities of 100 or more. Address Reader Service Dept., MATERIALS IN DESIGN ENGINEERING, *430 Park Ave., New York 22, N. Y.*

FILE FACTS

NICKEL ELECTROPLATES

USES

Because of their good corrosion resistance and favorable physical and mechanical properties, nickel electrodeposits are used in numerous and diverse applications. Principal among the applications for nickel electrodeposits are: 1) decorative and industrial corrosion resistant coatings in matte, semibright and bright finishes; 2) coatings to build up worn or mismachined parts; 3) electroformed parts; and 4) coatings for nonconductors.

BASIS METALS PLATED

Aluminum and its alloys
Beryllium copper
Brass
Cast iron
Copper and its alloys
Inconel
Magnesium
Monel
Nickel (wrought and electrolytic)
Nickel-iron alloys
Nickel silver
Pewter
Lead-base alloys
Steel (carbon, nickel, tungsten and stainless steels)
Tin and tin-plate

(data sheet continued on p 139)

RECOMMENDED BASIS METAL PRETREATMENT[a]

Basis Metal	Application: Decorative	Application: Industrial	Sequence of Pretreatment Operations
Aluminum	X	X	Two general classes of pretreatment processes available: 1) application of immersion deposits (such as zincate process); and 2) variations of anodizing (such as phosphoric acid anodizing process)
Brass	X		Degreasing + cathodic and anodic alkaline cleaning + cold water rinse + muriatic acid dip + cold rinse
Brass		X	Degreasing + cathodic alkaline cleaning + pumice scrub + cold rinse + nitric acid dip
Cast iron	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment
Copper	X		Degreasing + cathodic and anodic alkaline cleaning + cold rinse + sodium cyanide dip + cold rinse + cold sulfuric acid dip + cold rinse
Copper		X	Degreasing + cathodic alkaline cleaning + pumice scrub + cold rinse + nitric acid dip + cold rinse
Copper Alloys		X	Degreasing + cathodic alkaline cleaning + pumice scrub + cold rinse + etch in cold solution of nitric-sulfuric-hydrochloric acid + cold rinse + dip in sodium hydroxide and potassium persulfate solution + cold rinse + short dip in 1% (by vol) sulfuric acid solution + cold rinse
Inconel	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + treatment in acid nickel chloride solution
Monel	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment + cold rinse
Nickel (wrought)		X	Degreasing cathodic alkaline cleaning + pumice scrub + cold rinse anodic alkaline cleaning + cold rinse + anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment
Nickel (electrolytic)	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + treatment in low pH Watts type or all-chloride nickel bath + cold rinse
Nickel-Iron Alloys	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment
Steels (carbon)	X		Degreasing + cathodic and anodic alkaline cleaning + cold rinse + hydrochloric acid dip + cold rinse
Steels (carbon)		X	Degreasing + cathodic alkaline cleaning + pumice scrub + cold rinse + anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment + cold rinse
Steels (nickel)	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment + cold rinse
Steels (stainless)	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + treatment in acid nickel chloride solution
Steels (tungsten)	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment + cold rinse + treatment in acid nickel chloride solution (cathodic only)
Tin or Tinplate	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + cyanide copper plating + cold rinse + acid ammonium citrate solution treatment + cold rinse
Zinc	X	X	Treatment in solvent degreaser or emulsion slush cleaner + soak cleaning + warm water rinse + anodic cleaning + cold water rinse + dip in 2% sulfuric acid solution + cold water rinse + copper plate + cold water rinse

[a]Basis metal surface should be smooth and free of scale and tarnish. Rapid transfer of parts from last pretreatment operation to plating bath is recommended.

EVER TRIED MACHINING A SPECIAL I.D. SHAPE?

—in stainless steel, with each part 22 inches long, the outside diameter a shade over 2 inches and with tolerances of +.000" to −.010" across the flats?

On jobs like this, there's possible trouble ahead if you start with solid stock, or even round heavy wall tubing. Machining problems, surface finishing, scrap loss, special cutting oils or compounds—added to the original stock cost may make the final cost of the part prohibitive.

There is one sure way of minimizing your production problems and costs involving hollow cylindrical parts and products—*DESIGN WITH B&W MECHANICAL TUBING.*

Before you start your next production run, call Mr. Tubes at your nearby B&W Tubular Products Division District Sales Office—let him match tubing steels, types, finishes, shapes and tolerances to your applications—he will show you how to keep final costs low. Or write for bulletins 361 and 340. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

B&W
TUBULAR PRODUCTS DIVISION

TA-6086-M2

Seamless and welded tubular products, seamless welded fittings and forged steel flanges—in carbon, alloy and stainless steels.

For more information, turn to Reader Service card, circle No. 381

FILE FACTS

Nickel Electroplates (continued)

COMMONLY USED PLATING BATHS

Watts The Watts type bath is the most commonly used plating bath and is very flexible with respect to composition, current density and temperature. The bath is used to obtain a decorative matte finish or a bright finish subsequent to polishing or buffing. It is also used to build up worn or mismachined parts that are subject to wear. Relatively thick deposits are used for electroforming and to prevent corrosion of steel pipe and other equipment used for the processing of chemicals, petroleum and foods. The baths are usually grouped into two classifications on the basis of operating pH:

	High pH	Low pH
Nickel sulfate, oz/gal	32	44
Nickel chloride, oz/gal	6	6
Boric acid, oz/gal	4	5
pH	4.5-6.0	1.5-4.5
Temperature, F	115-160	115-140
Current density, amp/sq ft	20-100	25-100

Advantages of the low pH bath (commonly known as the soft nickel bath or general purpose bath) over the high pH bath are: 1) higher current densities (resulting in increased output) can be used without causing deposit peeling or cracking; and 2) improved anode efficiency decreases nickel salt consumption. Disadvantages of the low pH bath are: 1) lower throwing power at low current densities; 2) tendency to pit at some points in the pH range; and 3) lower cathode efficiency.

Chloride-Sulfate This bath produces deposits with modified characteristics of the Watts type and all-chloride baths.

Nickel sulfate, oz/gal	26	pH	1.5
Nickel chloride, oz/gal	23	Temperature, F	115
Boric acid, oz/gal	5.3	Current density, amp/sq ft	25-100

The increased chloride concentration produces a smoother, finer grained, easier buffed deposit with less tendency to pit than the Watts bath. The bath can also be operated at lower voltages and higher current densities at greater cathode efficiency. Advantages claimed over the all-chloride bath are a more ductile deposit, easier pH control, simpler purification, and compatibility with available organic brighteners.

Hard Nickel This bath is used primarily when a deposit is needed which is tougher and less liable to crack and peel than chromium and where the extreme hardness of chromium is not essential. Deposits possess high resistance to wear and corrosion and are adaptable to conventional machining practices. If a heavy deposit with an extremely hard surface is required, a dual layer of hard nickel followed by chromium can be used.

Nickel sulfate, oz/gal	24	pH	5.6-5.9
Ammonium chloride	3.3	Temperature, F	110-140
Boric acid, oz/gal	4.0	Current density, amp/sq ft	25-50

THICKNESS OF DEPOSITS

Decorative applications: up to 0.5 mil
Corrosive applications: 3 to 15 mils
Applications to improve wear resistance: 0.002 to ¼ in.

PHYSICAL AND MECHANICAL PROPERTIES

Density, lb/cu in. 0.322
Specific Gravity 8.9
Melting Point, F 2640
Specific Heat (32-212 F), Btu/lb/°F 0.11
Coefficient of Expansion (32-212 F), per °F .... 7.5×10^{-6}

Thermal Conductivity (32-212 F), Btu/sq ft/hr/°F/in 470
Electrical Resistivity (68 F), microhm-cm 7.0
Modulus of Elasticity in Tension, psi .... 30×10^6
Tensile Strength, psi
- Soft Gray Deposits 51,000
- Hard Bright Deposits 140-160,000

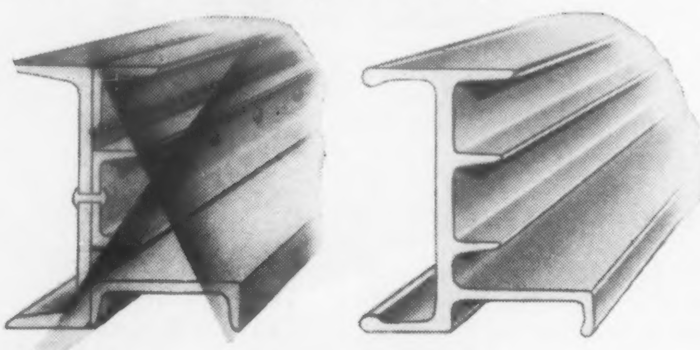
Elongation in 2 in., %
- Soft Deposits 30
- Bright Deposits 10

Vickers Hardness
- Soft Deposits 150
- Bright Deposits 475-525

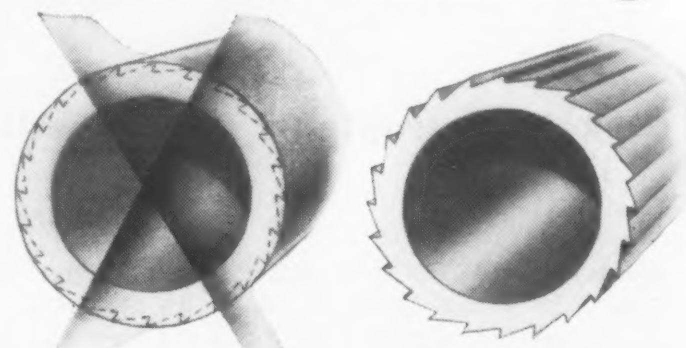
The help of Hanson-Van Winkle-Munning Co. and Harshaw Chemical Co. in preparing these data is gratefully acknowledged.

Cost-Cutting Aluminum Extrusions . . .

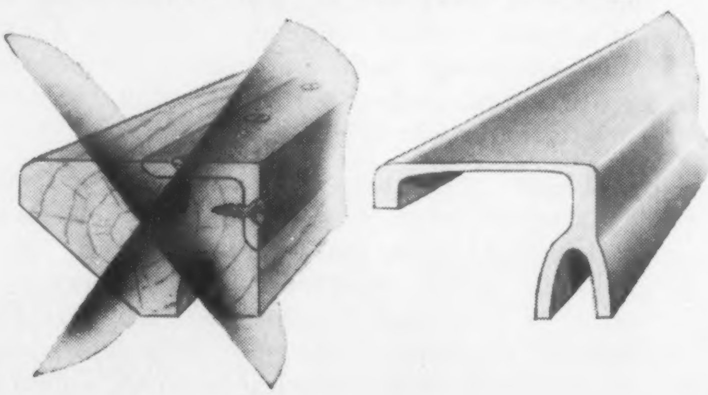
1. eliminate joining



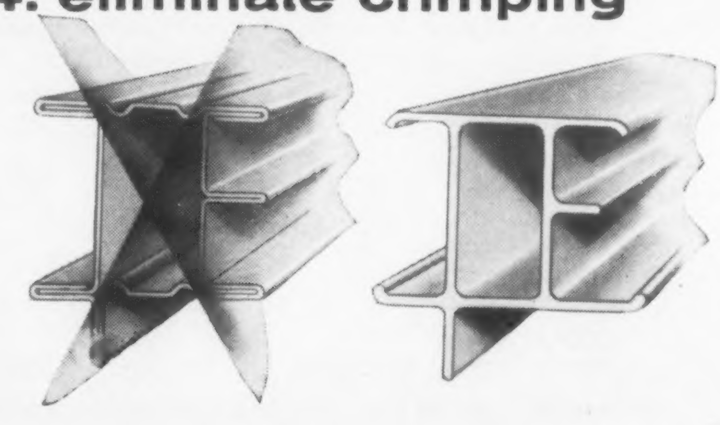
2. eliminate machining



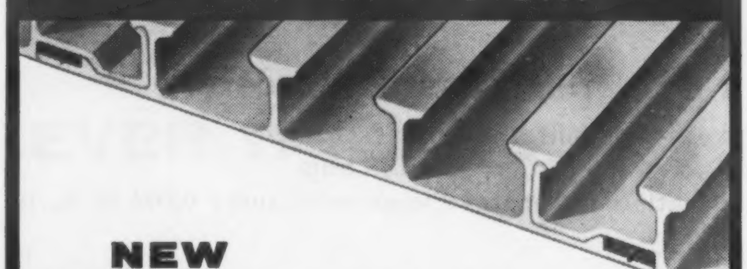
3. eliminate reinforcing



4. eliminate crimping



. HERE'S ONE WAY EXTRUSIONS SAVE AND IMPROVE . . .



NEW

Reynolds "ALL-AIR"* truck flooring

Here's a new Reynolds extruded aluminum product that really saves . . . both in production and in use. Made of simple, strong interlocking extruded aluminum panels, this new "All-Air" reefer flooring gives truck operators the light weight and heavy duty service they want. It would be impossible to produce this efficient, cost-cutting flooring any other way, in any other metal.

*TRADE MARK; U.S. PAT. PENDING

The Finest Products Made with Aluminum

are made with

REYNOLDS ALUMINUM

It's quite likely that your plant is producing part of a product that could be improved—at a lower cost—by an aluminum extrusion. You can turn out the most complex shapes through low-cost, accurate extrusion dies—and you can often minimize or eliminate machining, joining and finishing operations.

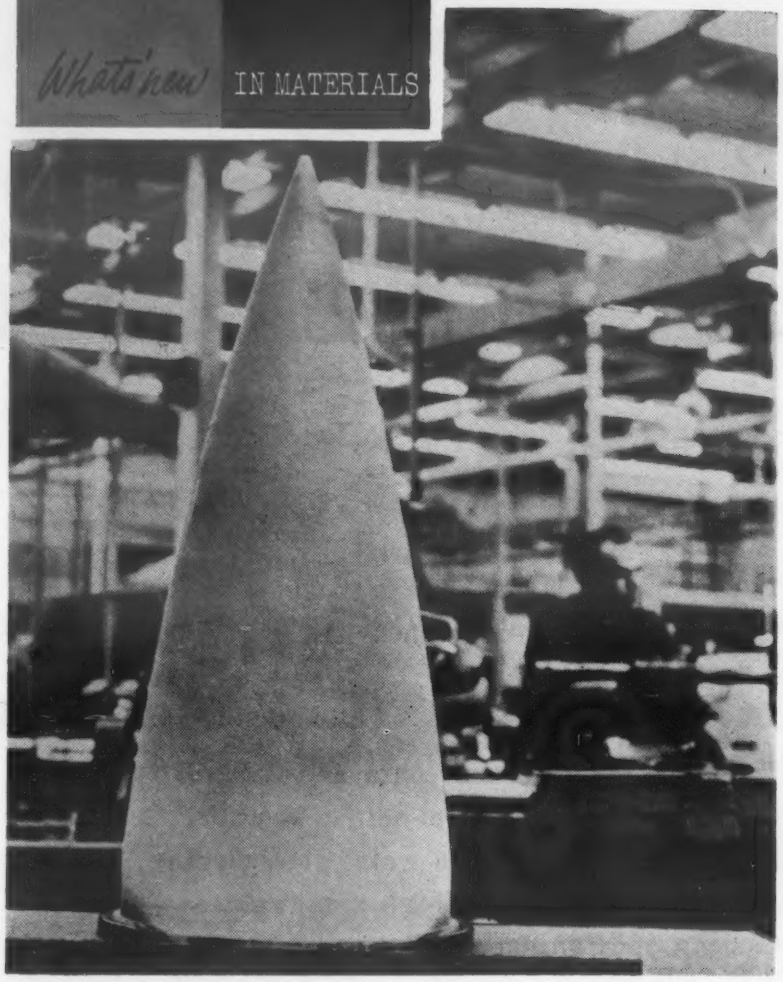
For example, in No. 1 above, a single aluminum extrusion replaces several rolled structural shapes that have to be joined. In No. 2, extruded aluminum tubing does away with the need for machining ordinary tubing or rod. Or, in No. 3, a stiffer, lighter, stronger extruded aluminum shape does the work of a wood-supported metal angle. And, as in No. 4, an aluminum extrusion provides the required shape with added stiffness and without investment in expensive roller dies.

Reynolds Design and Engineering Services will work with engineers and design consultants in improving and cutting the cost of your products with extrusions and other forms of aluminum. For their assistance or to obtain a complete aluminum literature and movie index, call the Reynolds office, listed under "Aluminum" in your classified phone book. Or write *Reynolds Metals Company, P. O. Box 1800-HM, Louisville 1, Kentucky.*

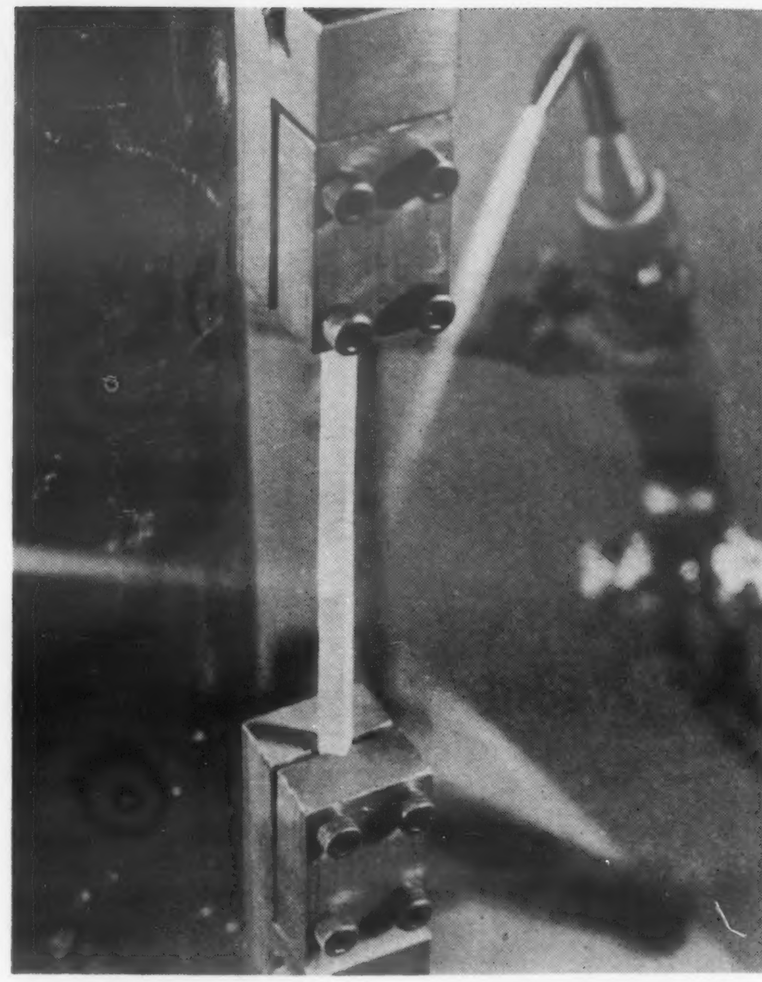
For more information, turn to Reader Service card, circle No. 495

What's new IN MATERIALS

Contents



***First commercial product** made of Pyroceram ceramics is a radome for guided missiles.*



***Stressed ceramic rod** is not affected by heat from acetylene torch.*

Pyroceram: A Strong New Ceramic

■ A newly developed family of ceramic materials can be fabricated by any of the conventional glass forming techniques. Developed by Corning Glass Works, Corning, N.Y., and called Pyroceram, the materials offer an interesting combination of high mechanical strength, light weight, high hardness, good dielectric properties, good resistance to chemical attack, and excellent thermal shock resistance (as indicated by thermal expansion coefficients ranging from slightly negative to 2.6×10^{-6}).

Pyroceram: What It Is

Pyroceram is the trade name for a group of materials that are essentially crystallized glasses. Pyrocerams can be made from a variety of specialty glasses, permitting a wide range of physical, electrical and thermal properties. A glass batch containing one or more nucleating agents is melted, formed and cooled. After cooling, the material is still a noncrystalline glass. Subsequent heat treating causes the nucleating agents to form submicroscopic crystallites, each crystallite acting as a center of crystal growth as the heat continues. The end product, after heat treatment, is a fine-grained crystalline material, nonporous and harder than most ceramics and many metals.

Properties

Although more than 400 types of Pyroceram have been melted experimentally, only four have been melted in pilot runs. Known typical properties of two are shown in an accompanying table. Three types are opaque and the fourth is transparent. Pyrocerams suffer only slight losses of mechanical strength at temperatures up to 1300 F, though at about 1450 F modulus of rupture falls off rather rapidly, as shown in the accompanying curve. No data are available on impact strength or ductility of the materials.

Formability—Probably the most important advantage of the materials is their formability by conventional glass forming techniques. Since the materials are glass (see box), they can be blown, pressed, drawn, rolled and centrifugally cast.

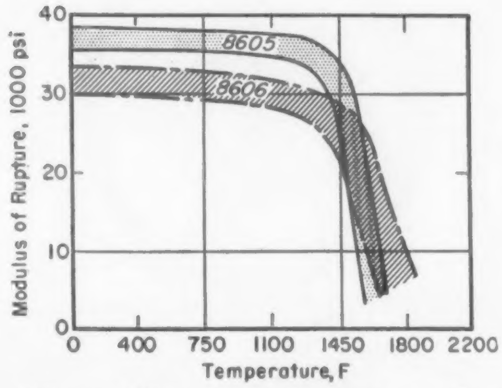
According to the producer, a relatively high degree of dimensional accuracy can be obtained by investment casting even though some dimensional change takes place during heat treatment. Usually the dimensional change is on the order of slightly less than 2%, or even less with some compositions. It is recommended that machining of Pyrocerams be carried out before heat treatment because of their high hardness. The material cannot be machined after the ceramic has been formed but can be finish ground with carbide and other abrasives.

Strength — Pyroceram 8605 is the strongest of the four materials. It has a modulus of rupture (flexural strength) of 37,000 psi and is extremely resistant to abrasion. In comparative diamond indentation tests Pyroceram 8605 was harder than flint, granite or hardened high carbon steel (Rockwell C65), but not as hard as sapphire.

Electrical properties—The family of ceramic materials is said to have electrical properties comparable to those of the best electrical ceramics. For instance, the dielectric loss factor of Pyroceram 8605 at a frequency of 10^{10} cycles per sec is 0.0022 at room temperature and 0.013 at 930 F. According to the producer, dielectric loss factor of the ceramic is two-thirds that of dense alumina at the same frequency.

Thermal properties — The low thermal expansion and high tensile strength of certain Pyroceram ceramic materials is said to make them extremely resistant to thermal shock. For instance, Pyroceram 8607 has a thermal shock resistance greater than that of dense alumina and equivalent to that of fused silica. Thermal conductivity values of Pyroceram 8607 are said to be about three times higher than those of borosilicate glass.

Chemical properties—According to the producer, long term chemical resistance tests on Pyrocerams are not yet completed. However, preliminary tests show that the



***How high temperatures** affect flexure strength of two Pyrocerams.*

ceramic materials are nearly as resistant to acid attack as borosilicate glass and are more resistant to alkali attack than this glass.

Possible applications

William C. Decker, Corning Glass Works president, has listed these possible uses for Pyroceram ceramic materials: parts for supersonic aircraft, jet engine components, and piping for chemical and oil refining plants. He predicts that Pyroceram materials "will be used in the kitchen some day as a heat conducting, range top material."

According to the producer, the ceramic materials will probably cost little more than glass and less than stainless steel.

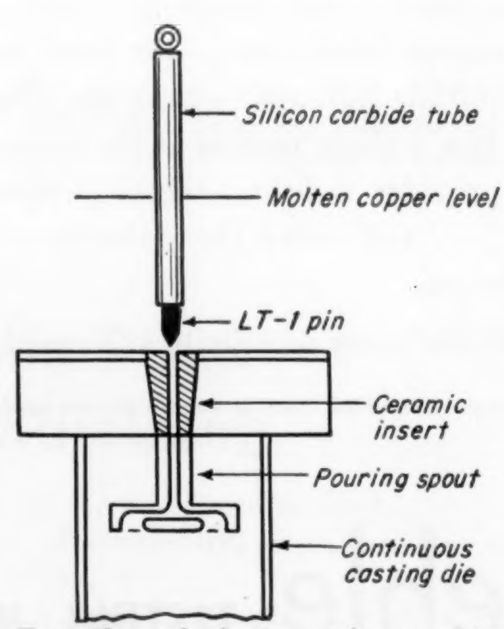
PROPERTIES OF PYROCERAMS

Type ➤	8605 (Opaque)	8606 (Opaque)
Modulus of Elasticity, psi	19.8 x 10^6	17.8 x 10^6
Modulus of Rupture, psi	37 x 10^3	32 x 10^3
Softening Temp, F	2462	2282
Water Absorption, %	0.00	0.00
Specific Gravity	2.62	2.60
Specific Heat, Btu/lb/°F	0.102	0.105
Ther Cond Btu/hr/sq ft/°F/ft	2.4	1.7
Knop Hardness (50 gm)	1100	940
Dielectric Constant		
1 MC	6.1	5.62
10^{10} Cycles	6.1	5.53
Dissipation Factor		
1 MC	0.0017	0.0024
10^{10} Cycles	0.0002	0.0003
Loss Factor		
1 MC	0.0102	0.0134
10^{10} Cycles	0.0012	0.0016
Volume Resistivity (500 F), ohm-cm	10.1	10.0

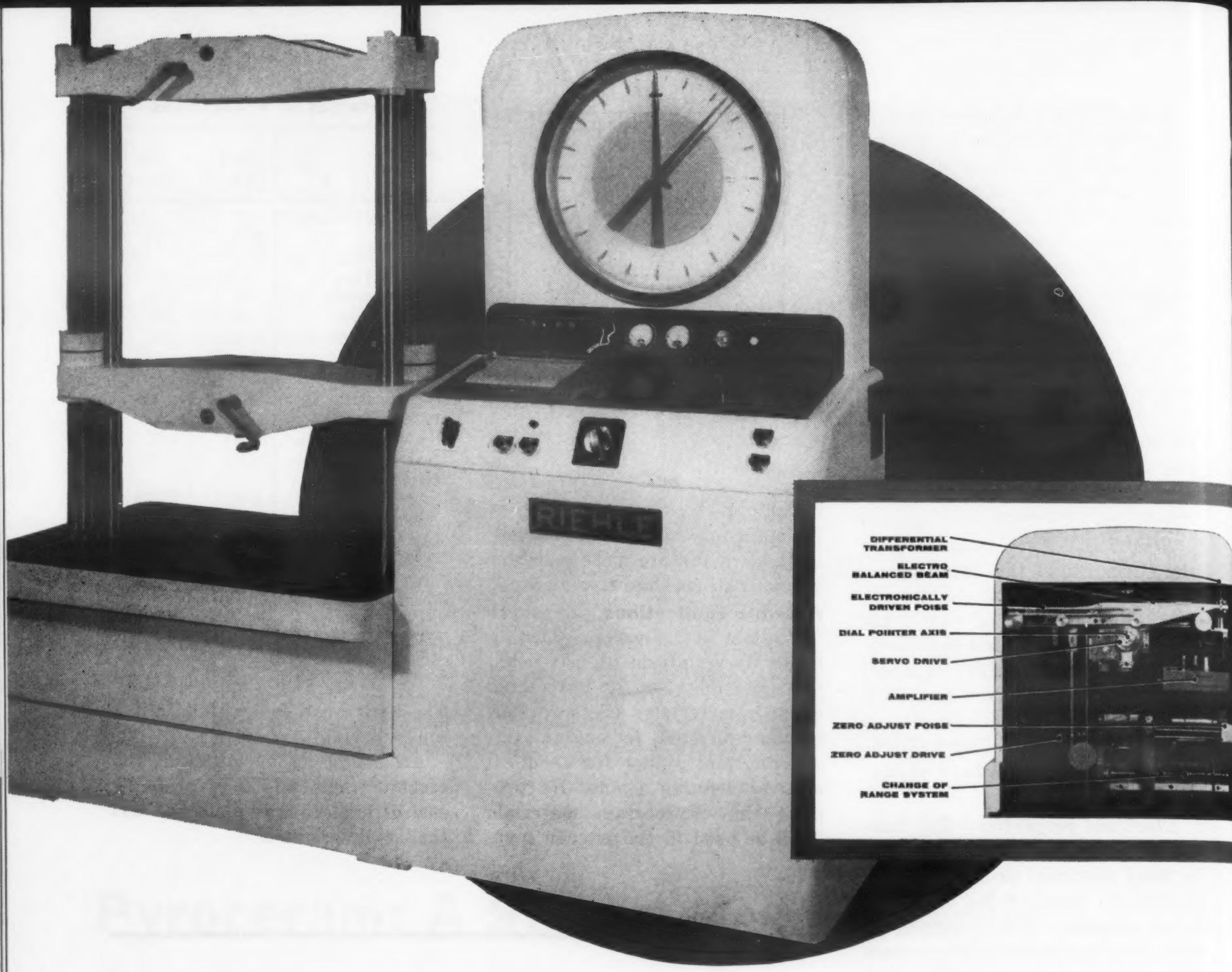
Cermet Pin Controls Copper Flow in Continuous Casting Machine

■ A metal-ceramic (cermet) pin has solved the problem of controlling the flow of molten copper in a continuous casting operation.

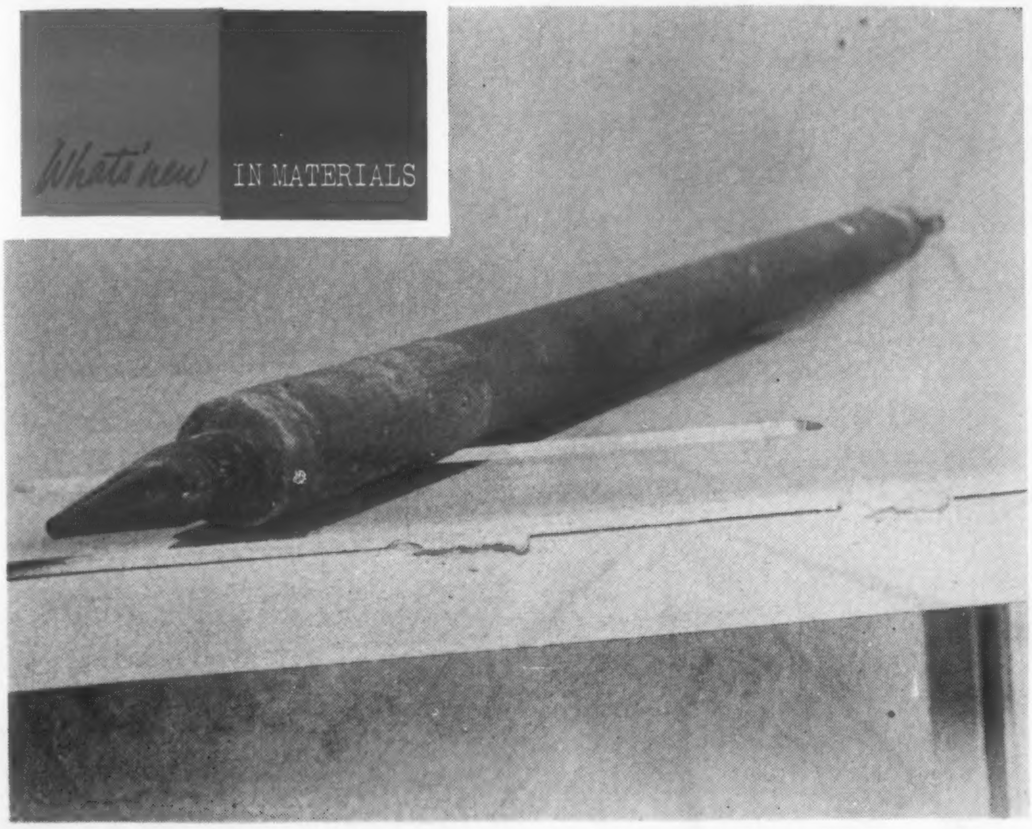
Called LT-1 and developed by Haynes Stellite Div., Union Carbide Corp., the cermet is composed of 77 chromium and 23% aluminum oxide. The material has good high temperature mechanical properties and high resistance to corrosion over a wide temperature range. Resistance is increased by the formation on the chromium of an oxide film which is tightly bonded and highly stable. There is also a bonding mechanism between the chromium and aluminum oxide that contributes to the



***Function of pin** in casting machine is shown in this sketch.*



RIEHLE
DIFFERENTIAL TRANSFORMER
ELECTRO BALANCED BEAM
ELECTRONICALLY DRIVEN POISE
DIAL POINTER AXIS
SERVO DRIVE
AMPLIFIER
ZERO ADJUST POISE
ZERO ADJUST DRIVE
CHANGE OF RANGE SYSTEM



LT-1 cermet pin *as installed in the end of the control tube.*

PROPERTIES OF LT-1

Density, lb/cu in.	0.21
Hardness, Rockwell	C32-42
Melting Point, F	3362
Specific Heat, Btu/lb/°F	0.16
Coef of Ther Cond (500 F), Btu/in./sq ft/hr/°F	348
Coef of Ther Exp (32-1800 F)	4.7×10^6
Elec Res (rm temp), microhm-cm	87
Modulus of Rupture, psi	
Room Temperature	45,000
1500 F	43,000
1800 F	27,000
2100 F	21,000
2400 F	9,000
Compressive Strength (rm temp), psi	110,000
Shear Strength (rm temp), psi	40,000
Modulus of Elasticity (rm temp), psi	42×10^6
Charpy Impact Strength, ft-lb	
Room Temperature	2.1
1500 F	3.4
1800 F	4.1
Tensile Strength, psi	38,000
Poisson's Ratio	0.22
Modulus of Rigidity, psi	17×10^6

strength of the body at elevated temperatures.

According to Haynes, the use of LT-1 culminates a "long search for a material that would withstand the extremely severe erosion, temperature and thermal shock problems in this service." Other materials were tried with unsatisfactory results. Some broke immediately; others lasted only a week or two. The LT-1 pin has been in service for six months.

The LT-1 pin, technically known as a tapered valve, is 15 in. long and 1 in. in dia. When installed, about 4 in. of the tapered end of the pin extends out from a silicon carbide control tube. The taper starts 2½ in. from the end of the pin and is ¼ in. at the tip. The tapered pin seats in the silicon carbide in the bottom of the pouring furnace and is located just before the continuous casting die (see sketch). Its purpose is to regulate the flow of molten copper, much as a needle valve, in order to hold the level of the molten copper at a given point in the die.

According to Haynes, LT-1 combines four properties that make it ideal for this application:

1. Corrosion resistance. The material is resistant to oxidation and wetting by metals and basic slags and can be used for continuous immersion in brass and bronze melts. Both constituents, chromium and alumina, resist oxidizing atmospheres over 2200 F.

2. High temperature strength. Above about 2800 F the material begins to soften and turn plastic, but at lower temperatures it resists deformation. Repeated intermittent immersions at up to 3000 F have been accomplished successfully.

3. Hardness and wear resistance. The Rockwell C32-42 value (see accompanying table) is more indicative of the crushing strength of LT-1 than of hardness. The individual particles are harder than the combined body and give good resistance to wear under sliding friction.

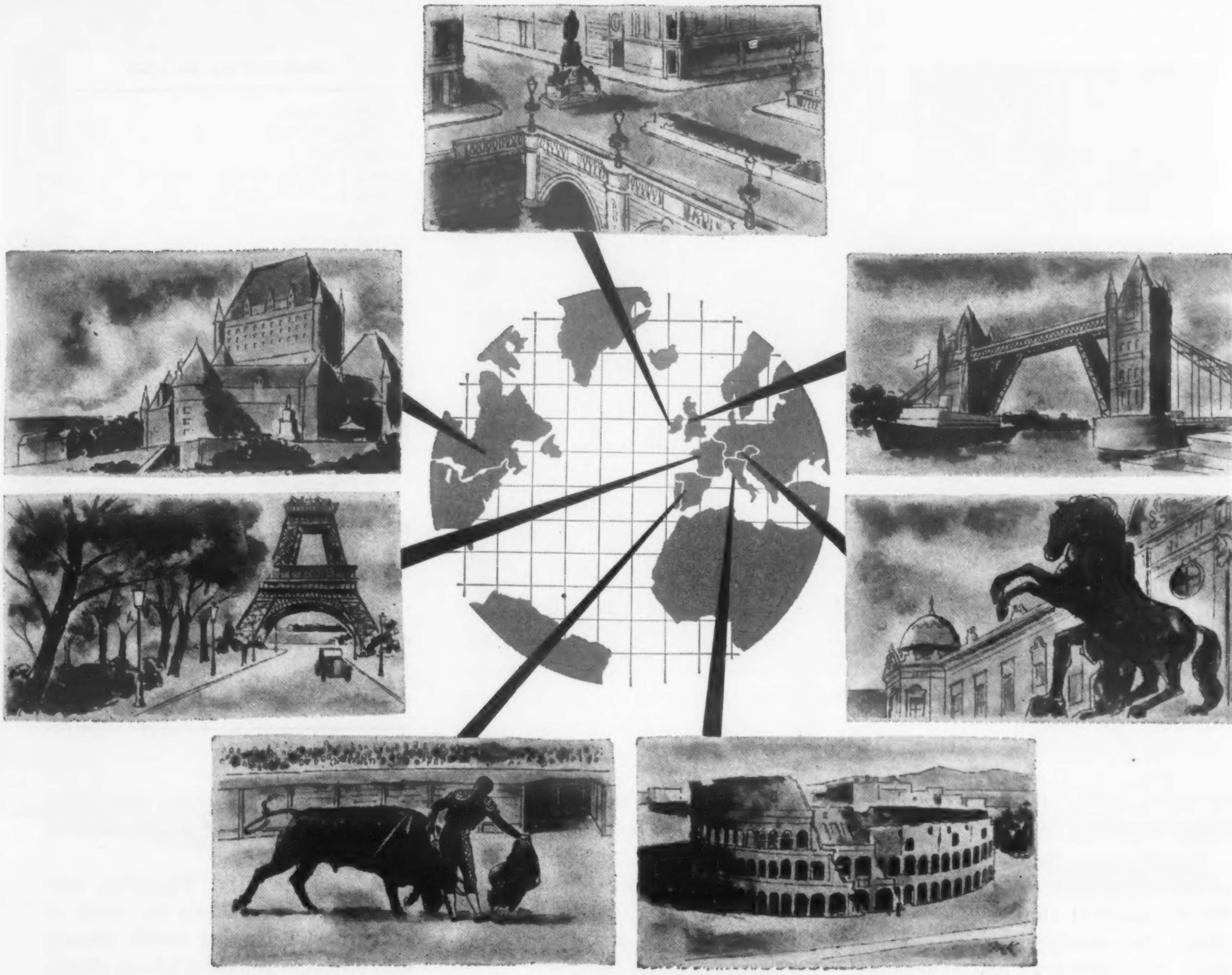
4. Machinability. Tungsten carbide-tipped tools can be used to machine LT-1 using feeds, speeds, etc., suitable for cobalt-base alloys. The material can also be ground and honed. Small brazed joints can be made, but larger joints depend on the geometry of the parts being brazed and their respective coefficients of thermal expansion and strength.

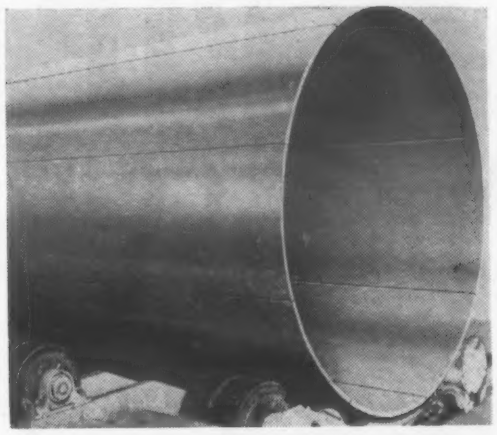
In addition to the above properties, the LT-1 material offers the advantage of salvageability. In the event erosion does become significant, the pin can be reground or a new taper can be machined.

1% Boron Stainless Steel Used for Atomic Shielding

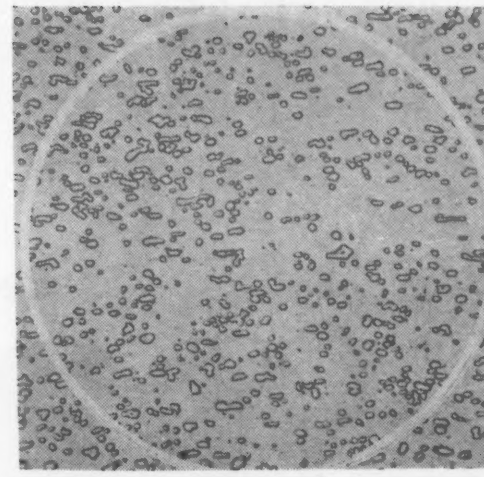
■ A new wrought 1% boron stainless steel, used in vital reactor shielding and control applications, is claimed to have thermal neutron absorption properties approximately 15 times greater than those of regular stainless steel.

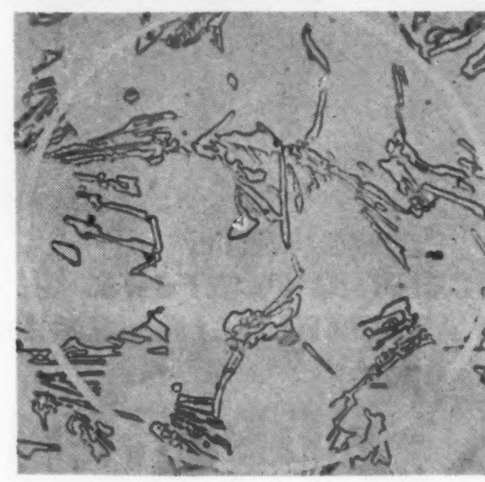
Manufactured by Superior Steel Corp., Carnegie, Pa., the new steel is available in plate, sheet, strip and bars; it is workable hot or cold; it is weldable, machinable





Thermal shield *of boron stainless is similar to the one installed in the Argonne Experimental Boiling Water Reactor.*





Microstructure *— as-cast (above) and as-rolled.*

and corrosion resistant; and it may also be used for such things as storage racks, boxes, etc.

Boron stainless steel is essentially a two-phase alloy composed of a complex boride phase in an austenitic chromium-nickel-iron matrix (see photos of microstructures). Boron stainless appears to have approximately the same resistance to hot water as regular 18-8 stainless steel. It has been tested in water at 550 F for extended periods of time for use in the experimental boiling water reactor. On welded structures, post-annealing treatments are recommended to improve resistance to acid corrosion.

Boron stainless steel is weldable to itself or other austenitic stainless alloys by electric arc or sigma welding. Sound welds are easily obtained in plate up to ½ in. thick. On heavier gages special techniques are necessary to produce good welds. Lime-coated type 308 welding rod is generally used for welding heavy sections. Currently, welds on boron stainless are used for shielding or sealing purposes, since the inherent properties of this material limit its use for welded structural members. To overcome this limitation, boron stainless steel clad with a standard austenitic stainless steel is being developed.

Use of the new material is claimed to make possible important savings in weight and space in various atomic energy components.

(more What's New on p 148)

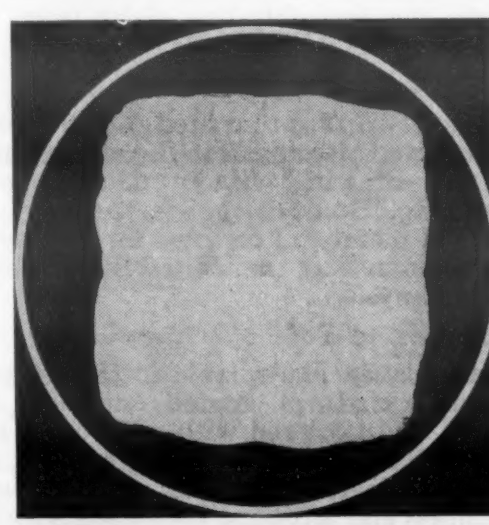
MECHANICAL PROPERTIES OF 1% BORON STEEL

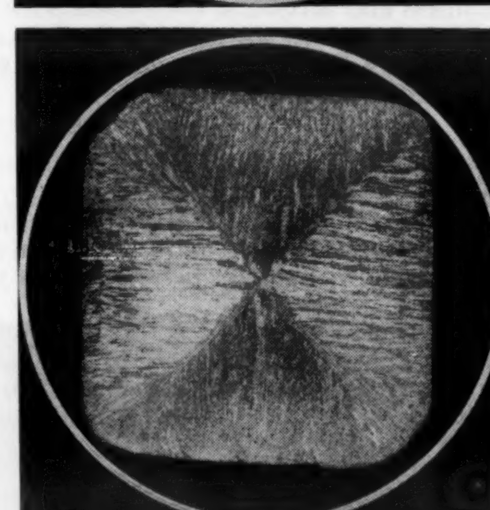
Tensile Strength, 1000 psi	90
Yield Strength (0.2% offset), 1000 psi	50
Elongation (in 2 in.), %	10-25[a]
Hardness, Rockwell	B90
Cold Bend[b]	
>0.375 In. Thk	180°
<0.375 In. Thk	90°
Density, lb/cu in.	0.287
Annealing Temperature, F	1800-1900
Melting Range, F	2350-2450
Thermal Conductivity, Btu/sq ft/hr/°F/in.	100

[a]Depends on thickness.
[b]Boron stainless is inherently notch sensitive due to its structure; therefore removal of cracked or work hardened edges, use of generous fillets, and removal of scratches and other stress raisers are recommended for successful bending or forming. Boron stainless steel is generally furnished in the annealed condition.

TYPICAL COMPOSITION, %

Carbon	0.08
Manganese	0.79
Silicon	0.63
Chromium	18.24
Nickel	10.95
Boron	1.09





Macrostructure *of 1% boron stainless steel ingot (above) compared with boron-free stainless. In boron-free stainless, the crystals extend into the center of the ingot; in 1% boron stainless, the grains are centered and equiaxed.*

What's new IN MATERIALS

***Coated filler** containing catalyst is placed in container around mold.*

Two-Part Resin System Contains Resin, Filler

Liquid casting resins, such as epoxy resins, are usually supplied in two or more parts that are mixed together to form a cured part such as electrical insulation for motor windings and coils.

Recently, Robert Herr and J. S. Casement, of Minnesota Mining and Mfg. Co., St. Paul, Minn., speaking before the Great Lakes district meeting of the AIEE in Des Moines, Ia., described a new approach to the use of liquid casting resins for use as electrical insulation. The authors describe the new resin system as a two part system that consists of a resin and coated inert fillers. The inert fillers contain a catalyst for subsequent resin cure.

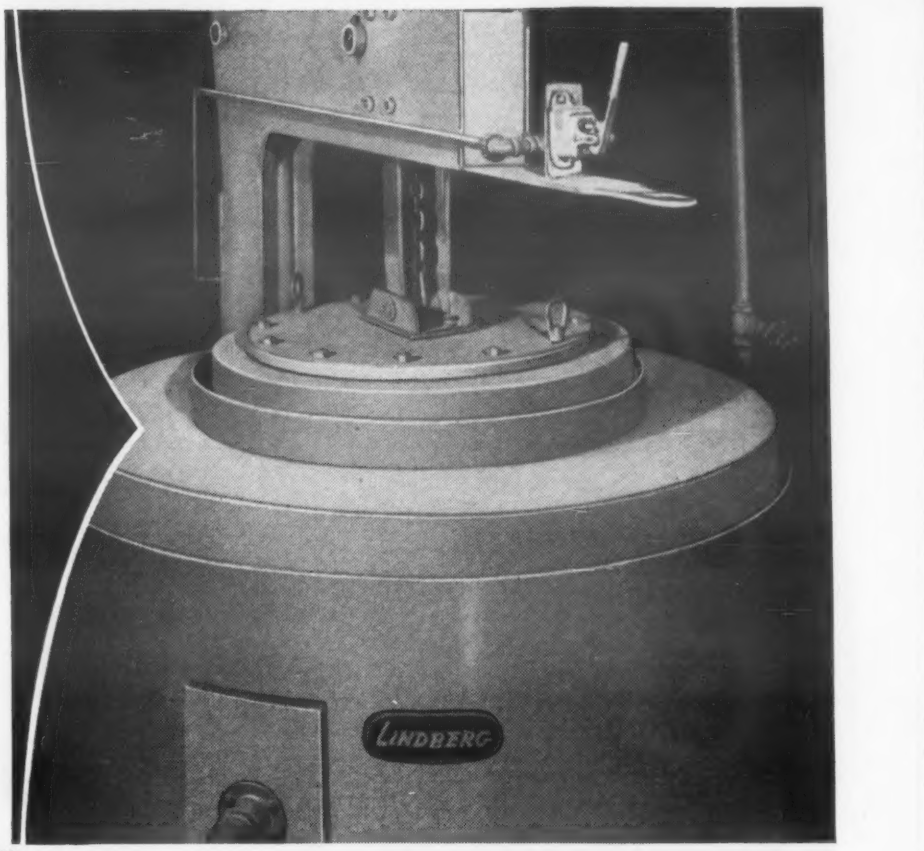
According to the authors, the resin system is applicable to many classes of resin-hardener systems and to different methods of impregnating, molding and encapsulating. A typical use for the resin system is in the impregnation and encapsulation of motor windings.

Advantages of system

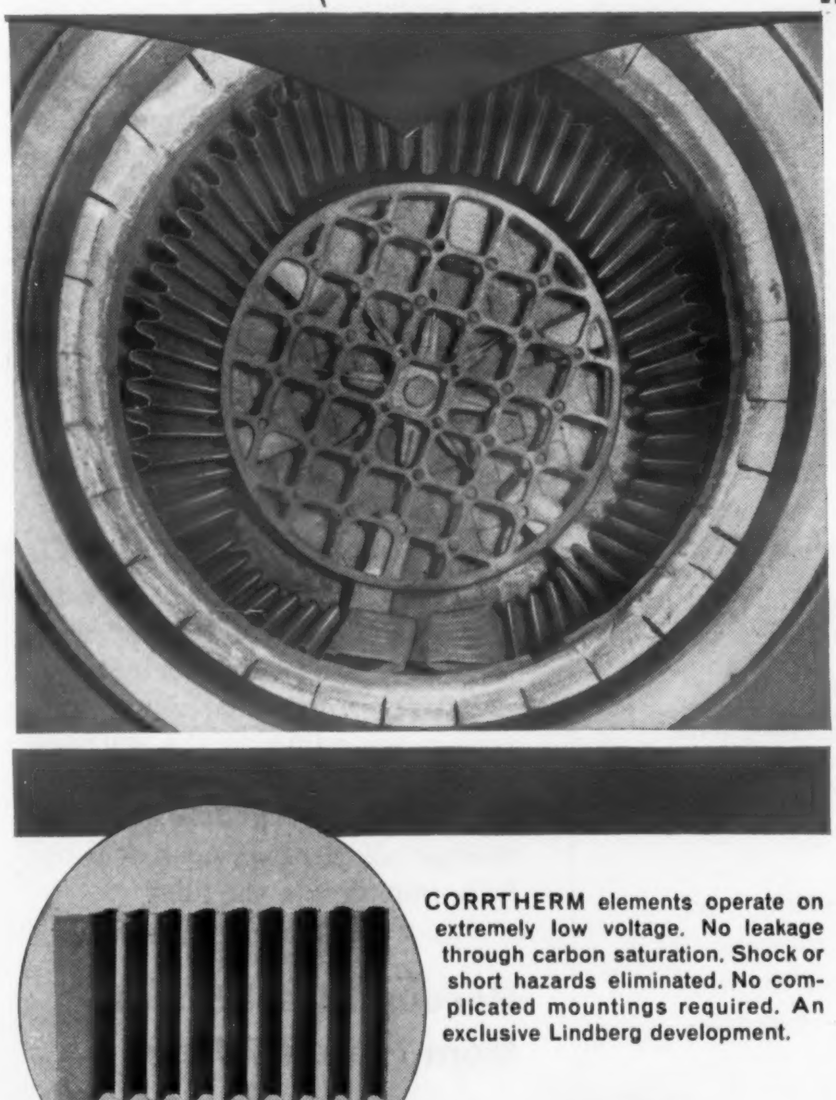
The new system is said to provide extremely long pot life for the resin and to eliminate long mixing operations. The system is also said to permit complete and accurate mixing of all ingredients

FROM THE OUTSIDE

. . . JUST ANOTHER LINDBERG PIT-TYPE CARBURIZING FURNACE



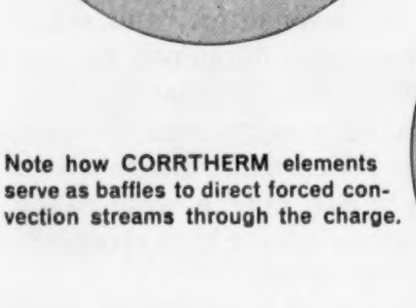
BUT LOOK INSIDE



No Retort!

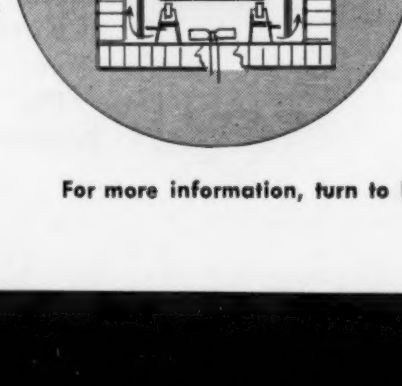
Because it needs no retort, this new Lindberg electric vertical pit-type furnace gives you these important advantages:

- **Lower initial cost, no retort to pay for.**
- **No expensive retort replacement.**
- **Downtime for retort replacement eliminated.**
- **Increased production because it heats faster.**
- **Exact atmosphere control maintains work quality.**
- **Versatile, carbon-diffusing and requenching along with carburizing. Adaptable to variety of work.**



CORRTHERM elements operate on extremely low voltage. No leakage through carbon saturation. Shock or short hazards eliminated. No complicated mountings required. An exclusive Lindberg development.

All this is made possible by Lindberg's new CORRTHERM electric heating element. For lower initial cost, lower maintenance costs, faster production, better quality control, why not look into this furnace. It's additional evidence that, if you're concerned with the application of heat to industry, better talk it over with Lindberg.



Note how CORRTHERM elements serve as baffles to direct forced convection streams through the charge.

LINDBERG
ENGINEERING COMPANY

2451 West Hubbard Street, Chicago 12, Illinois

Los Angeles Plant: 11937 S. Regentview Ave., at Downey, Calif.
Toronto Plant: EFCO-Lindberg, Ltd., 11 Front Street, East

For more information, turn to Reader Service card, circle No. 512

without entrapment of air bubbles in the resin.

According to the authors, the resin system permits inexpensive, inert filler contents of up to 82% filler by weight. This high filler content is said to result in very low shrinkage of the resin on cure and helps to reduce moisture absorption, weight loss on heat aging, and flammability. If weight or dissipation factor are more important than economy, other types of filler, such as polystyrene beads, are recommended.

Molding of resin

In molding the resin and coated filler, a mold is used for only a few minutes in the production of each part. This short molding cycle is said to be especially important in large scale production of inexpensive electrical parts. For such parts, conventionally cured resins have often been ruled out because of high molding costs.

Since the filler is impregnated with the resin by capillary action, vacuum impregnation is not required. However, the authors caution that since the resin is catalyzed primarily by contact with the coated filler, the filler must be thoroughly impregnated with the resin. According to the authors, merely passing the resin through the coated filler and further impregnating internal voids does not fully impregnate the filler.

Porous Metal Sheet from Felted Fibers

A new porous metal sheet material with potentially wide application in aeronautical and other fields has been developed by Armour Research Foundation. The material is a continuous sintered sheet of felted metal fibers which can be varied over a wide range of porosities having high strength-to-porosity ratios.

The new material is an outgrowth of the Foundation's work

with "fiber metallurgy" (see MATERIALS & METHODS, Nov '55, p 96). Degree of porosity, controlled by diameter and length of fibers, ranges from 94% down to less than 1%. A brazing material having a lower melting temperature can be added to improve strength and ductility. After sintering, the sheet can be pressed for desired density.

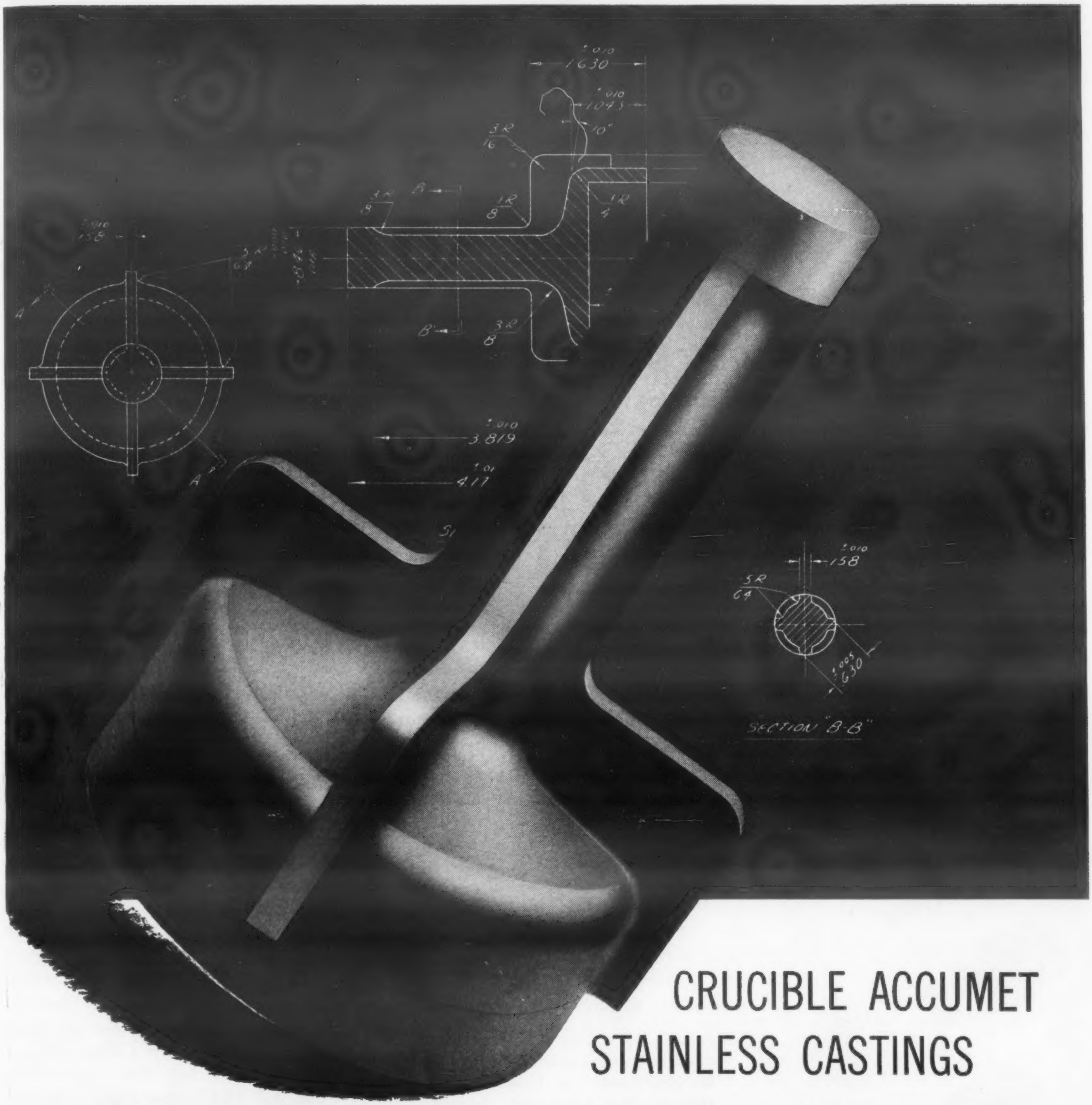
Developed by Cord H. Sump, supervisor of powder metallurgy at Armour Research Foundation, and William Pollack, associate metallurgist, the new material is expected to be used in high temperature filters for aircraft engines, as a honeycomb structure to fill tail and rudder sections, as a porous material for transpiration cooling systems, and for aircraft boundary layer control.

Other applications appear to be possible in ceramics and plastics, using the metal fibers as reinforcing agents. "Where they have been used in place of glass reinforcements," Mr. Sump said, "fibers provide a high elastic modulus, and they avoid problems of abrasion."

Polystyrene 'Wheel' Aids Water Conditioning

A "dispenser wheel" used for conditioning water in Norge automatic washing machines is molded of polystyrene. The device, which perches atop the ma-

Bottom view *of dispenser wheel.*


SECTION "B-B"

For more information, turn to Reader Service card, circle No. 426

What's new IN MATERIALS

***Polystyrene dispenser wheel** operates on the principle of centrifugal force to apply water conditioner.*

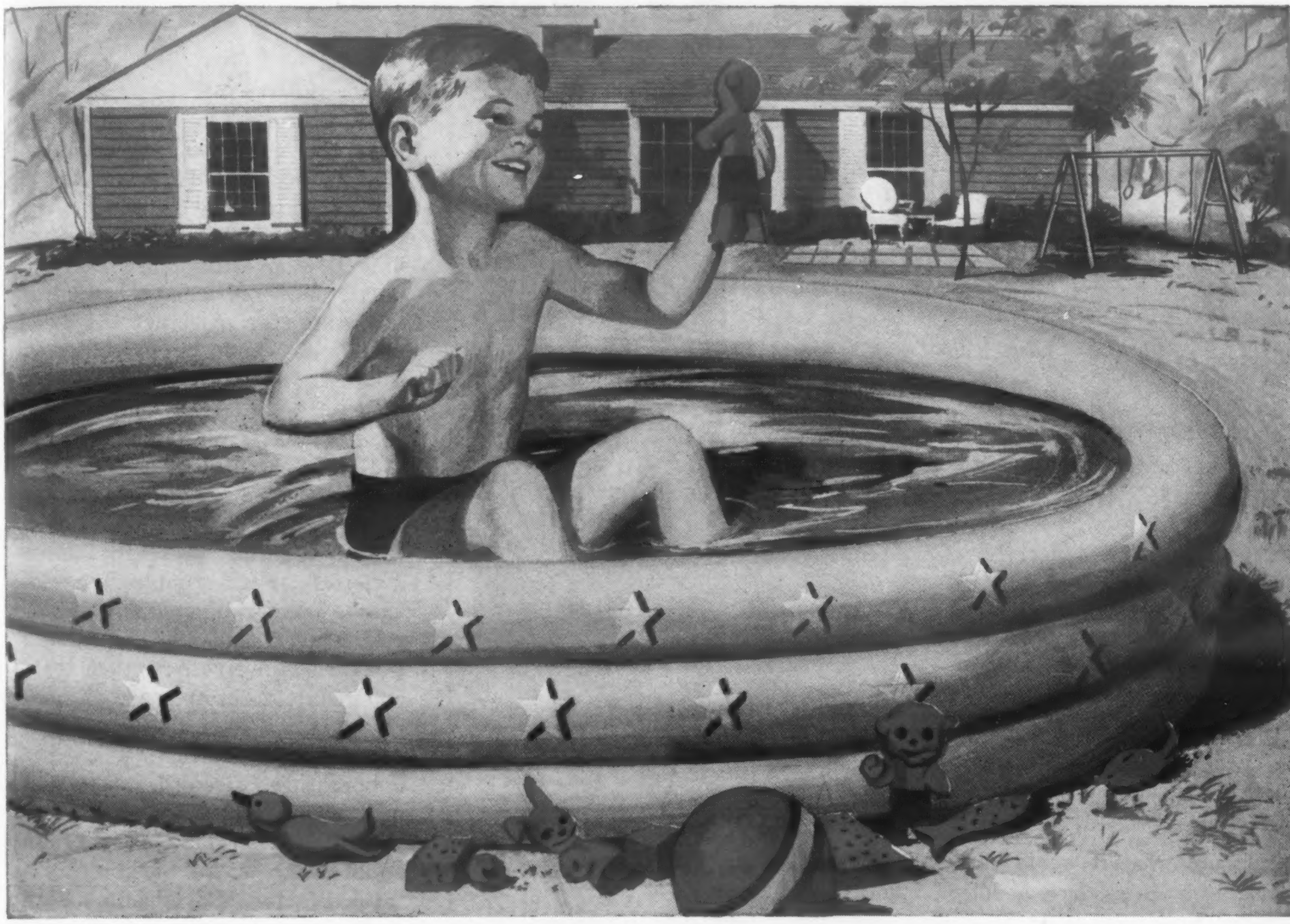
chine's agitator and operates on the principle of centrifugal force, automatically applies water conditioner to the wash during the rinse cycle.

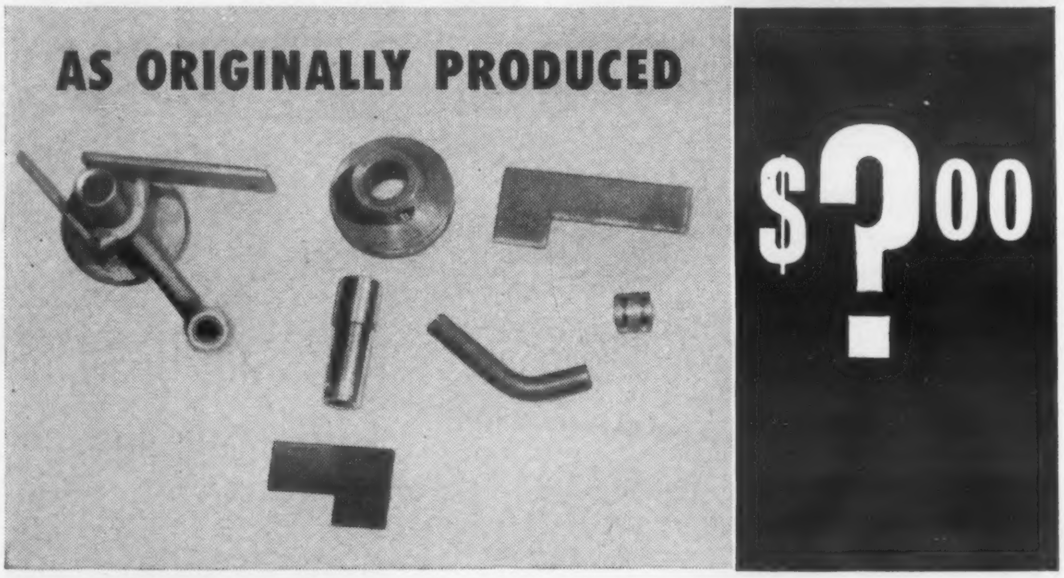
The inner chamber of the device is manually filled with liquid water conditioner when the clothes are placed in the machine. During the spin cycle, centrifugal force causes the liquid to spill over into the outer chamber (see photo of bottom view). When the agitator stops for the rinse cycle, the liquid runs out into the wash water through openings in the bottom of the device.

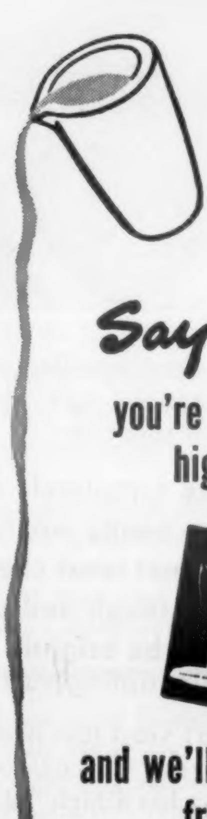
Styron 440 (Dow Chemical Co.) was chosen for the application because of its high impact strength and high resistance to heat distortion. In addition, it has a low water absorption rate, can be readily molded on standard injection equipment, and is well suited to applications requiring a high gloss and fine surface texture.

Use of Molybdenum at High Temperatures

In the attempt to secure better high temperature materials for aircraft applications, several molybdenum-base alloys have been developed during the past few years. Many of these alloys exhibit







What's new IN MATERIALS

outstanding high temperature strength.

At the National Aeronautic Meeting of the Society of Automotive Engineers held in April, R. T. Begley, Aviation Gas Turbine Div., Westinghouse Electric Corp., delivered a paper on "Molybdenum for Aircraft Applications" in which he presented a summary of latest developments. Here is a digest of his findings.

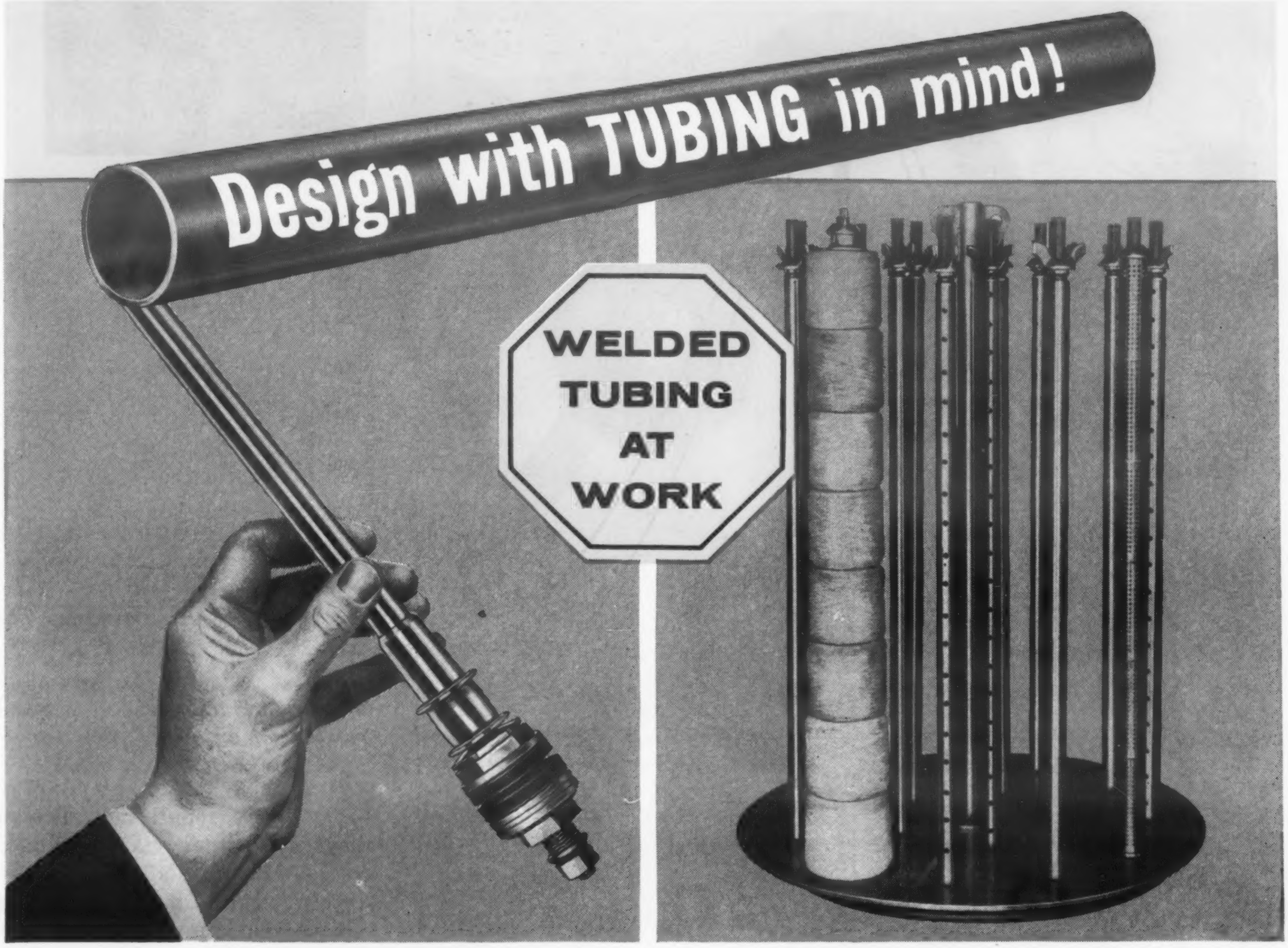
Advantages of molybdenum

Molybdenum alloys have been found to have higher useful strength at temperatures over 1600 F than any presently known materials. For example, the elevated temperature ductility of molybdenum and its alloys, final elongation in stress-rupture tests and reduction in area are all generally better than those of other materials. In addition to its high temperature strength, molybdenum has a high modulus of elasticity, a desirable property in applications where buckling is a critical factor. Molybdenum's high thermal conductivity is effective in reducing "hot spots" in components where nonuniform tem-

PHYSICAL PROPERTIES OF MOLYBDENUM[a]

Atomic Number	42
Crystal Structure	Body Centered Cubic
Melting Point, F	4730
Density, lb/cu in.	0.369
Ther Cond, Btu/hr/sq ft/ft/°F	
200 F	74.0
1200 F	62.5
1800 F	57.5
Coef of Ther Exp, in./in./°F	
32 - 200 F	2.67×10^{-6}
32 - 1200 F	3.05×10^{-6}
32 - 1600 F	3.21×10^{-6}
32 - 2000 F	3.36×10^{6}
Modulus of Elasticity, psi	
80 F	46.0×10^{6}
500 F	43.2×10^{6}
1200 F	41.0×10^{6}
1400 F	39.9×10^{6}
1600 F	39.9×10^{6}
Poisson's Ratio	
80 F	0.324
1600 F	0.321

[a]Data given for unalloyed molybdenum.



This spindle turns at 10,000 RPM without a jitter—that's the benefit of Welded Carbon Steel Tubing's "on-center" uniformity of roundness, wall thickness and concentricity.

Corrosion Resistant Welded Stainless Steel Tubing withstands constant contact with chemical dyes, pressure and wear in this packaging yarn dyeing equipment.

For 10,000 RPM's or fighting corrosion

CHOOSE WELDED STEEL TUBING

Carbon • Alloy • Stainless Steel

Welded Tubing replaces solid sections for most high RPM applications because of direct savings and better results. Welded Tubing's broad and uniform characteristics help to solve problems ranging from high strength-to-weight ratios through pressure, temperature and corrosive applications. Only Welded Tubing has these advantages. For all tubing applications, consult a quality tubing producer.

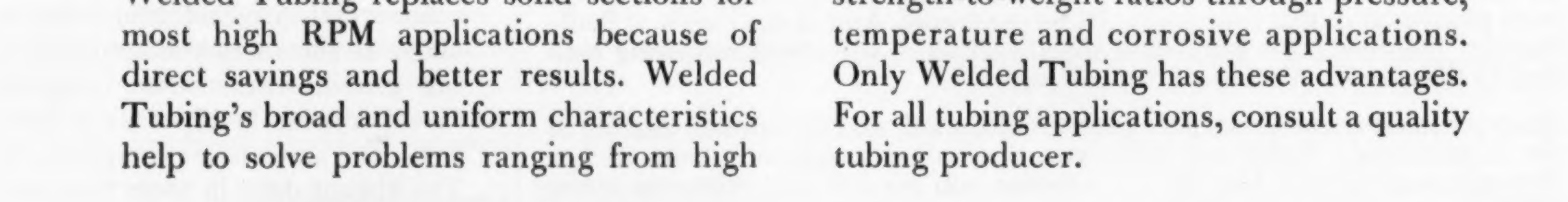
FORMED STEEL TUBE INSTITUTE
FSTI

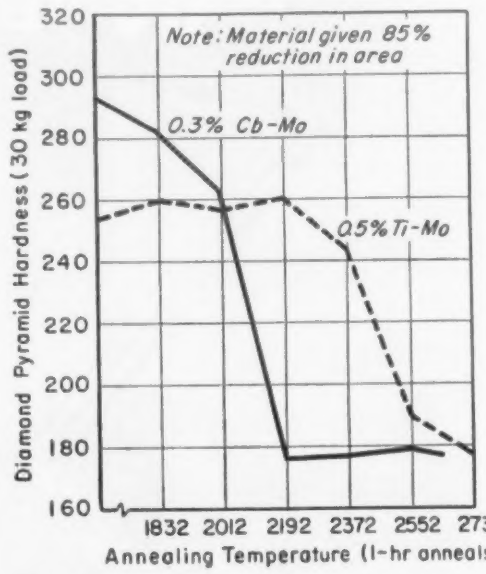
An Association of Quality Tube Producers

Design inspiration for you

The 260-page Handbook of Welded Steel Tubing contains inspiration and data for tubing designs. For your copy, write on your company letterhead, giving your title.

FORMED STEEL TUBE INSTITUTE
850 HANNA BUILDING • CLEVELAND, OHIO





Hardness *as a function of annealing temperature for two arc-cast molybdenum alloys.*

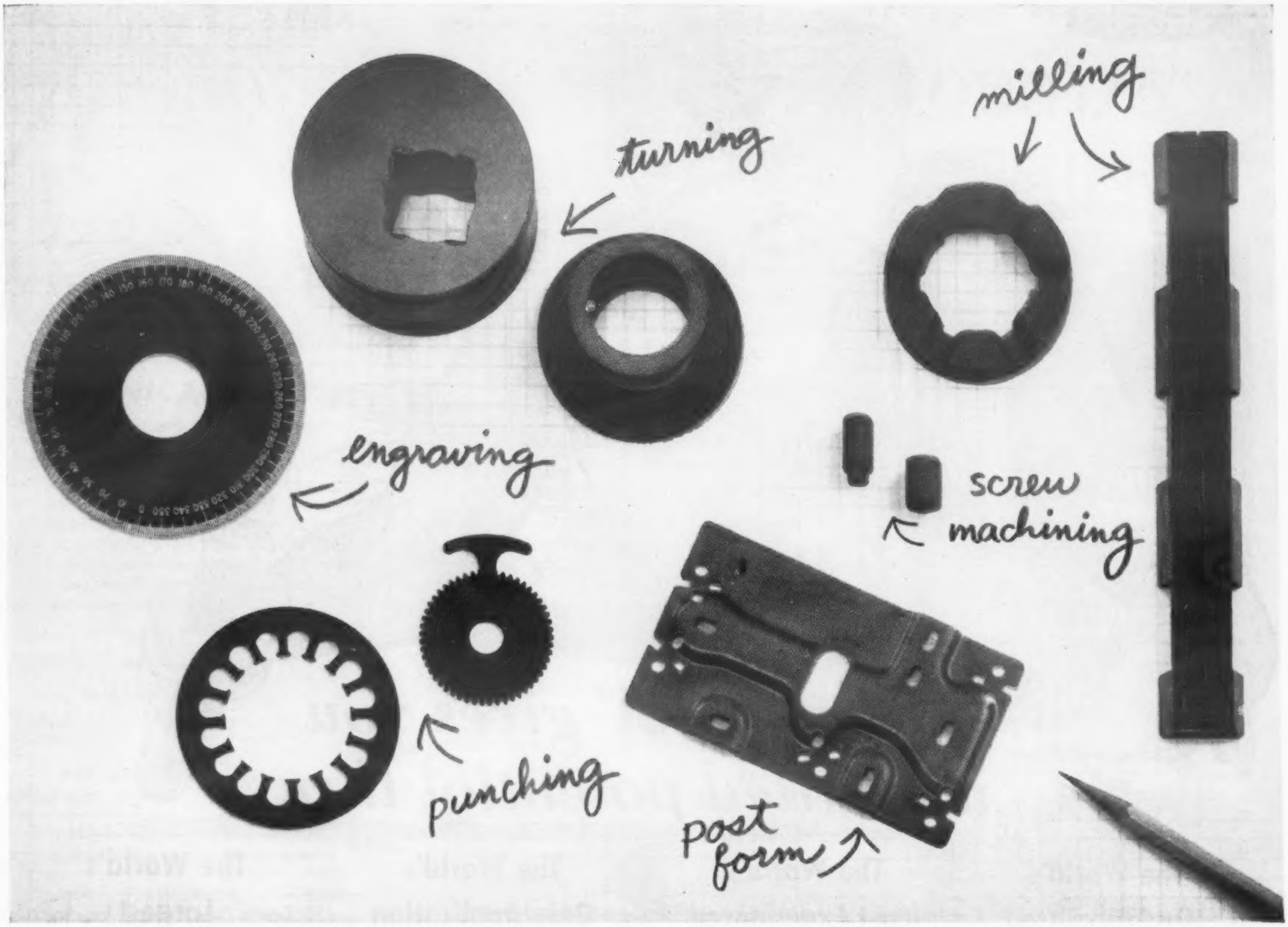
perature distribution is a problem.

The high strength molybdenum alloys now commercially available are solid solution alloys that rely largely on strain hardening to achieve maximum strength. One of the most important characteristics of molybdenum-base alloys is the recrystallization temperature. Since these alloys derive their excellent elevated temperature strength through mechanical working, the recrystallization temperature sets an upper limit to the operating temperatures at which the beneficial effects of mechanical working may be retained. The recrystallization behavior of two commercial arc-cast molybdenum alloys is shown in the accompanying graph, where room temperature hardness is given as a function of annealing temperature. The abrupt drop in room temperature hardness with increasing annealing temperature indicates the occurrence of recrystallization.

Disadvantages

There are three main disadvantages in the use of molybdenum for aircraft applications:

1. High density. The relatively high density of molybdenum (approximately 25% greater than conventional turbine blade materials) is definitely a disadvantage, particularly in rotating compo-



For fabricated plastic laminates...

LET MICA MAKE IT!

It makes sense... saves dollars, too... to use MICA'S *experience, facilities and know-how to design, fabricate and machine your laminated plastics requirements.*

If it's savings you're after, let MICA make it. You get quality, uniformity, prompt delivery. Consistency of base materials and workmanship all are our undivided responsibility. We know our materials and their working properties, and have equipment specially adapted for this work.

If it needs special properties, let MICA make it. We produce phenolic, melamine, silicone, polyester and epoxy laminates with paper, linen, canvas, asbestos and fibrous glass bases. Properties can be readily varied to meet special requirements.

If it needs special machining, let MICA make it. We're equipped to do punching, drilling, routing, sawing, turning, tapping, boring, threading, milling, engraving, hot stamping, fungus-proofing, plus many special operations.

If it needs creative engineering, let MICA make it. With our knowledge of a wide variety of materials, our complete fabrication facilities and our experience with thousands of applications, we can design and manufacture prototype materials and parts, and conduct tests, experimental and development work through every stage to delivery of finished parts.

We can also mold parts of glass-reinforced polyester resin and SCOTCHPLY® reinforced plastic.

If you have a fabrication problem now, send us prints and specifications for a prompt quotation. If engineering assistance is needed, we'll be glad to work with you.

SCOTCHPLY® *is a registered trademark of Minnesota Mining and Manufacturing Co.*

MICA INSULATOR COMPANY SCHENECTADY 1, NEW YORK

Subsidiary of Minnesota Mining and Manufacturing Co.

MICO ELECTRICAL INSULATION ®

For more information, turn to Reader Service card, circle No. 480

chem-o-sol® is *Super Plastisol . . .*

Chem-o-sol is our trade name for specially formulated polyvinyl dispersions (plastisols), which free the designer from the limitations of conventional materials. Inherently versatile because of their "liquid solid" nature, these dispersions offer unlimited opportunity to solve old problems and to develop new products, new forms, new characteristics. They are simple to apply, whether adapted as coatings and finishes or as shaped components.

To give you the ultimate in this new production tool, we operate the world's largest plant — with the most modern facilities for research, application method development, and production of specialized formulations.

Call on these facilities to improve your present production, create new products, open entirely new fields.

Chemical Products
CORPORATION
KING PHILIP ROAD • EAST PROVIDENCE, R. I.
Member Vinyl Dispersions Division of The S.P.I.

See opposite page for technical data

For more information, turn to Reader Service card, circle No. 465

What's new IN MATERIALS

nents. However, the strength-weight ratio of molybdenum-base alloys is still significantly superior to that of conventional super-alloys at temperatures over 1600 F.

2. Difficulty of obtaining high strength joints. Molybdenum and its alloys may be fabricated by most conventional techniques, but the problem of obtaining ductile, high strength joints has not been fully solved. Satisfactory welding methods have been developed for a number of applications, however.

3. Absolute lack of oxidation resistance. The most serious obstacle to successful utilization of the outstanding high temperature properties of molybdenum-base alloys in aircraft applications is the oxidation problem. The volatility of molybdenum trioxide (MoO_3) prevents the formation of a protective oxide layer at elevated temperatures. The volatilization of the trioxide begins at about 932 F and at temperatures above 1450 F is very rapid, resulting in an extremely large loss of surface. The nature of this oxide restricts the likelihood of discovering an alloy addition, or additions, which would form a protective oxide layer. Because of molybdenum's complete lack of oxidation resistance, some form of protective coating must be applied if this material is to be used in oxidizing atmospheres at temperatures over 1000 F.

Coating requirements

The requirements for a coating that will successfully protect molybdenum components at elevated temperatures depend, of course, on the temperature range, length of exposure, and environmental conditions. For use in gas turbine components such as turbine blades and nozzle vanes operating at temperatures in the range 1800-2100 F, the following requirements must be met:

1. Satisfactory oxidation resistance. The coating must be capable of affording consistent protection

For more information, turn to Reader Service card, circle No. 470

What's new IN MATERIALS

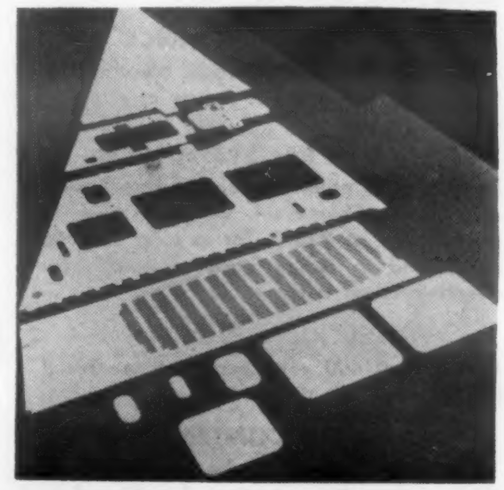
for 50-100 hr, and must be free of porosity and pinholes.

2. Impact resistance. The coatings must be able to absorb the impact of small particles of debris that normally pass through the turbine during engine operation.

3. Thermal shock resistance. A successful coating must withstand the rapid heating and cooling encountered during operation without cracking or spalling. This problem is aggravated by the large dissimilarity in coefficient of thermal expansion between molybdenum and the common oxidation resistant alloys.

4. Erosion resistance. The coating must have satisfactory resistance to the erosive action of the high velocity gas stream and small particles of sand, oxides, etc.

5. Ductility. The coating should be capable of withstanding 1-2%



Aluminum "wing" skins—Shown here is an array of Convair delta wing interceptor sculptured components made by Tapered Air Products Corp. These skins and structural components are machined from 5/16 in. thick 2024 aluminum stock to sections as thin as 0.055 in. on machines especially designed and constructed for the purpose. As much as 75-85% of the metal is removed during machining. These integrally stiffened aircraft skins and structural members offer great advantages in weight and strength, as well as savings in assembly time, compared with assemblies of panels and stiffeners formerly used.

creep strain in 100 hr without fracturing.

6. Compatibility with base metal. The coating should not interact with the molybdenum base to lower considerably the recrystallization temperature or to impart brittleness.

7. Ease of application. The coating should be capable of being applied below the recrystallization temperature of the molybdenum alloy, and the method of application should be suitable for coating complex shapes. The coating surface should be smooth, so as not to present aerodynamic problems.

8. Ease of handling. A practical coating must be sufficiently rugged at room temperature to withstand normal handling during installation without failure.

A wide variety of coating materials and methods of application has been investigated in recent years. In the course of this work several coatings have been developed which provide protection for molybdenum in laboratory tests for periods in excess of 100 hr at 2000 F, and for considerably longer times at lower temperatures. Since no one coating has demonstrated superiority under all conditions, coating selection is largely determined by the service conditions of the particular part. The coatings listed below (see Harwood, J. J., "Protecting Molybdenum at High Temperatures," MATERIALS & METHODS, Dec. '56, p 84) appear to be the most promising at present:

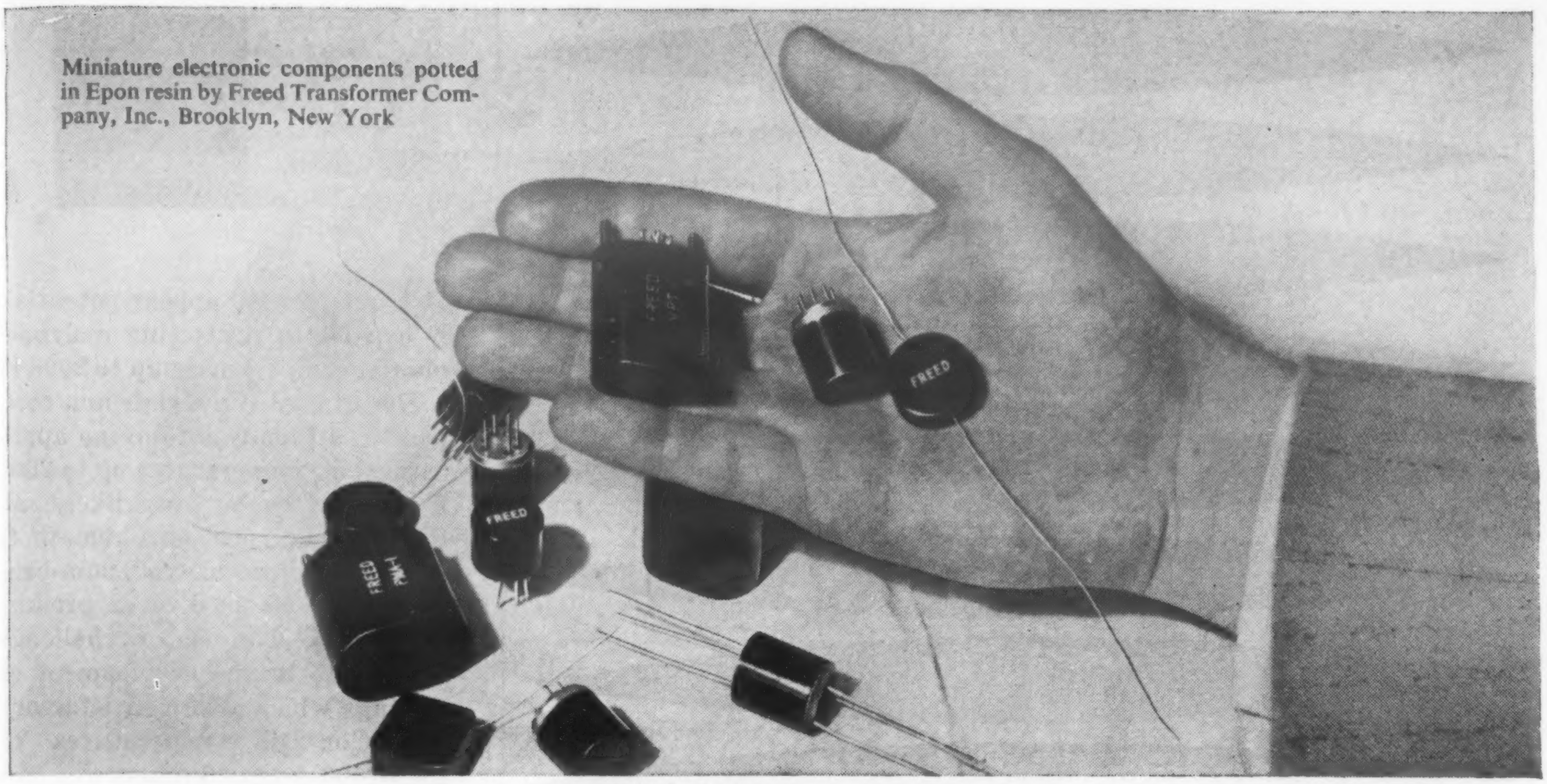
1. Electrodeposited chromium-nickel coatings.

2. Aluminum-chromium-silicon sprayed metal coatings.

3. Claddings of nickel and nickel-chromium alloys.

4. Nickel-chromium-boron coatings applied by metal spraying or brazing techniques.

These coatings vary considerably in their impact resistance, thermal shock behavior, ductility,

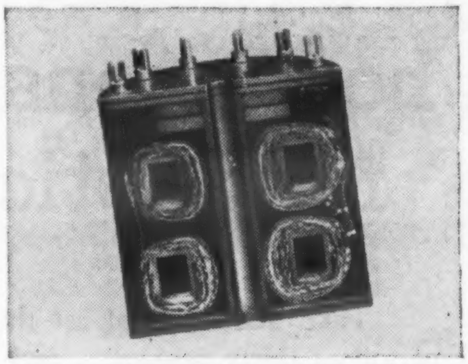


Miniature electronic components potted in Epon resin by Freed Transformer Company, Inc., Brooklyn, New York

Why EPON® RESINS for potting?

4 Good Reasons!

1. Outstanding adhesion to metal, glass, plastics
2. Excellent dimensional stability
3. High mechanical strength
4. Excellent dielectric properties



Section of magnetic amplifier coils embedded in Epon resin by Westinghouse Electric Corporation, Pittsburgh, Pa.

EPON RESINS are preferred for potting, laminating, sealing and encapsulating because they offer an almost ideal combination of electrical and physical properties.

Potting and encapsulating. Epon resins have outstanding adhesive properties. They form strong bonds to metal and glass, provide airtight enclosure of delicate components and vacuum tubes. They also have excellent dimensional stability and can withstand solder bath temperatures.

Sealing. Enamels and varnishes based on Epon resins provide excellent moisture sealing plus outstanding resistance to solvents and chemicals, even at elevated temperatures.

Laminating. Epon resins, laid up with inert fibrous fillers, produce base laminates of superior dielectric properties which can be sheared, punched, drilled and bath soldered.

Adhesives. Solvent-free Epon resin formulations cure at room temperature, with contact pressure alone; form powerful bonds between glass, metal, wood or plastic.

Write for complete information on the use of Epon resins in protective enamels, tool and die materials, etched circuit laminates, transformer and motor sealing compounds.

Potting transformer with Epon resin at PCA Electronics, Inc., Santa Monica, Calif.

SHELL CHEMICAL CORPORATION

CHEMICAL SALES DIVISION 380 Madison Avenue, New York 17, New York

Atlanta • Boston • Chicago • Cleveland • Detroit • Houston • Los Angeles • Newark • New York • San Francisco • St. Louis
IN CANADA: Chemical Division, Shell Oil Company of Canada, Limited • Montreal • Toronto • Vancouver

For more information, turn to Reader Service card, circle No. 410

etc., but they all appear potentially capable of protecting molybdenum at temperatures up to 2000 F.

Use of coated molybdenum components in many jet engine applications at temperatures up to 2000 F appears to be very likely, although many problems remain to be solved before molybdenum-base alloys can be used on a production basis. The major challenge appears to be the development of coatings which afford satisfactory protection at temperatures of 2500-2600 F and higher.

Casting of Titanium May Be Possible Soon

Significant progress toward the development of a process for casting titanium has been achieved at Battelle Memorial Institute. Although full-scale commercial operations are not yet possible, "sufficient research has been done in several laboratories and industrial organizations to indicate that there is sound metallurgical basis for the establishment of a titanium casting industry," according to Battelle metallurgists.

The melting and casting of titanium is complicated by the necessity for excluding air from the melt, since oxygen and nitrogen dissolve in titanium very rapidly and cause it to become brittle and difficult to machine. The melting process is further complicated because molten titanium reacts with or dissolves all known refractories.

A major breakthrough in titanium casting awaits the development of an inexpensive, inert and expendable mold material. At the present time the best molds for producing sound, smooth titanium castings with a minimum amount of surface contamination are those machined from solid blocks of graphite, which are relatively expensive.

Battelle metallurgists report

that Skull melting furnaces appear to be quite promising for the casting of titanium. With a water cooled copper crucible and a consumable electrode made from compressed sponge, titanium ingot or pieces of welded scrap, such furnaces have been used by the Bureau of Mines to pour castings weighing up to 100 lb. Rapid melting is accomplished by the use of a high current density and reduced pressure. Fixed electrode furnaces have also been used on large castings, but adequate superheat has been more difficult to obtain.

Although little research has been done on titanium alloys, there is some indication that the alpha and the alpha-beta alloys are as castable as unalloyed titanium. In fact, the alpha and alpha-beta alloys may be a little easier to cast, because the metallic alloy additions usually lower the melting point; thus, melts can be superheated more easily.

Fluorocarbon Resin Resists Most Acids

A new entry has been made into the fluorocarbon resin field with the introduction of Genetron HL by Allied Chemical & Dye Corp., General Chemical Div., 40 Rector St., New York 6, N.Y. (For more information on Genetron HL, see MATERIALS & METHODS, June '57, p 129).

The high molecular weight trifluorochloroethylene polymer is said to be extremely resistant to practically all organic and inorganic corrosive liquids, including oxidizing acids and most organic solvents at ordinary temperatures. According to the producer, the material is attacked chemically only by extremely reactive materials such as molten alkali metals.

The fluorocarbon resin has good electrical, mechanical, low temperature and machining properties

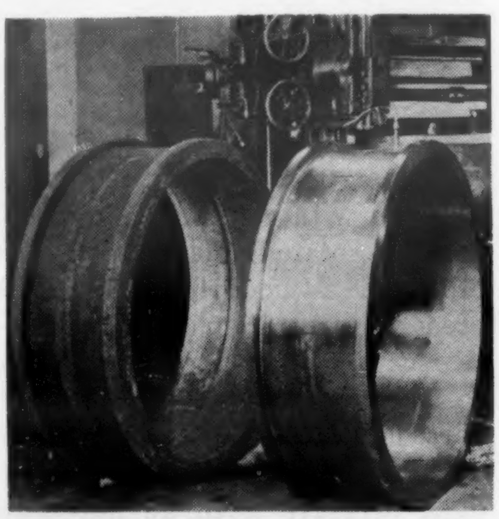
For more information, Circle No. 525 ➤

and can be molded by compression, transfer, injection and extrusion techniques. The material has good compressive strength and abrasion resistance and has a tensile strength comparable to that of other rigid thermoplastics. It may be used as a packaging film, as laboratory and hospital ware, as piping and tubing and as a wire coating.

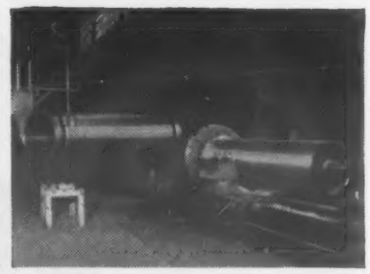
Synthetic Resin Films for Special Applications

A series of synthetic resin films, produced in sheets 38 in. wide, 3.5 mils thick and of any length, has been introduced recently by National Aluminate Corp., 6218 W. 66th Place, Chicago 38, Ill. Called Nalfilms, their characteristics such as film thickness, flexibility, strength, water content and perm-selectivity can be varied to meet special requirements.

Nalfilm-1 and subsequent odd



Centrifugal castings—These 60-in. dia, 1600-lb castings are used as separators in chemical plants. The centrifugal castings, made of 316 ELC stainless steel, are first welded together to form a double flanged drum; then 1300 holes are drilled through the wall. Casting, welding, machining are all performed by Wisconsin Stainless Foundry & Machine Corp.



numbered films are of the sulfonic acid group and contain mobile cations. Nalfilm-2 and subsequent even numbered films are of the quaternary ammonium chloride group and contain mobile anions. Nalfilm-1 is anionic and Nalfilm-2 is cationic.

The new products should find application in deionizing water; in radioactive waste disposal; in separating ionic mixtures; and as static-free battery separators.

'Spin Welding' Method Joins Plastics Parts

An improved plastics welding technique uses the frictional heat generated by the rotational rubbing of two plastics surfaces to melt and join plastics parts together. The improved technique, called spin welding, works especially well with such thermoplastic materials as nylon, acrylic and polyethylene resins. The process should be of interest to manufacturers of aerosol bottles since two sections of injection molded nylon can be joined to form a multi-colored bottle.

Developed at Du Pont's Sales Service Laboratory, Wilmington, Del., the technique is applicable to parts with circular joints that can be rotated against one another in a modified lathe, drill press or other device. One plastics part is held stationary in a special adapter while the other part is rotated against it. The plastics parts rub together under light pressure until an adequate melt is obtained. Pressure is then increased and the special adapter is released allowing both parts to spin together. This automatically stops the rubbing action and allows the weld to form. According to Du Pont, the cycle need be only long enough to insure complete welding of the part.

Excessive speeds create extreme vibration and extremely low

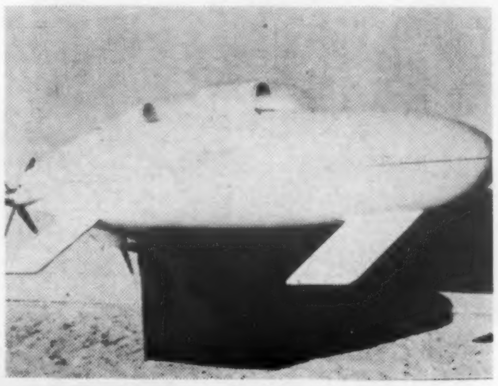

PRODUCED BY Keystone
FOR MIGHTY KIEKHAEFER MERCURY OUTBOARDS
THIS BRONZE POWDERED METAL SLEEVE
AVOIDS VIBRATION
IN CUSHIONED PROPELLER DRIVE
The rubber-cushioned flow of dynamic power to the Flo-torque propeller of four big Mercury engines is smoothed at the bearing point by a Keystone powdered metal part! Kiekhaefer Corporation molds this bronze insert integrally with the die-cast aluminum propeller housing. The sleeve assures positive alignment of propeller, eliminates development of vibration, and supplies built-in longevity. ● Do *you* have a bearing problem? Bring it to Keystone—always at your service!
Propeller Hub
Keystone Sleeve
Keystone CARBON COMPANY
ST. MARYS, PA.
For more information, turn to Reader Service card, circle No. 466

speeds tend to produce a grinding and shearing action. Best results have been obtained by increasing the pressure after initial melting to prevent degradation of the material. The pressure must also be great enough to force out any air bubbles which may form in the joint.

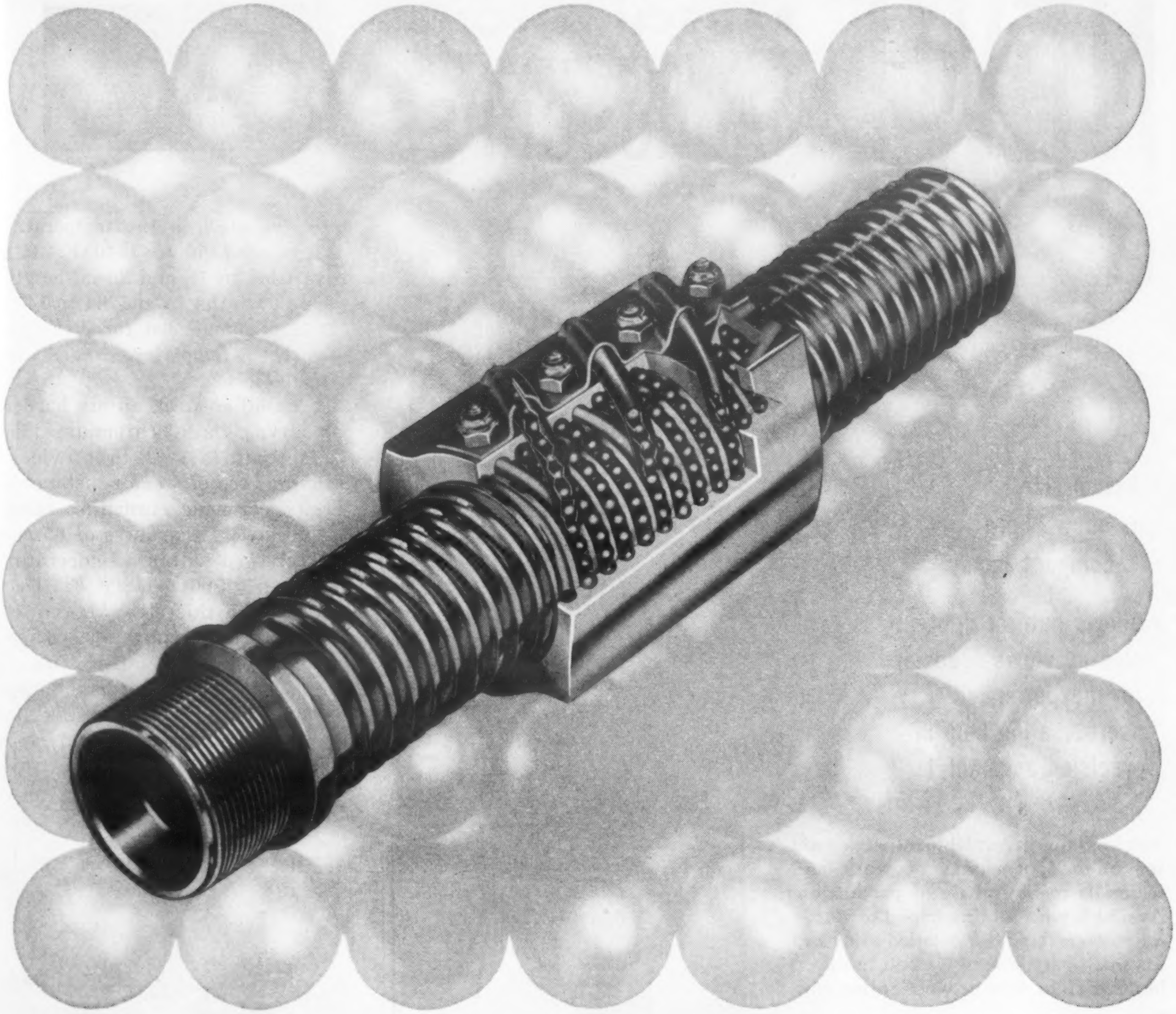
Two Types of Die Steel Available in 1300 Sizes

Heller Tool Co., Newcomerstown, Ohio, has introduced two types of flat ground die steels for tool and die applications. According to the company, over 1300 stock sizes are available in the two types of steel.

One steel, an oil hardening type, is a molybdenum alloy steel that has been annealed for easy machinability. According to the producer, a Rockwell C hardness of 65 may be achieved by harden-



Plastics submarine—A small, two-man plastics and steel submarine is being used by Quest Associates to search for sunken treasure. The hull and control vanes of the submarine are made by molding plastics–glass cloth laminates over a steel frame. The hull has access hatches with plastics domes, similar to a fighter type aircraft, that afford easy entrance and exit as well as good visibility. Called the MiniSub Mark VI, the submarine measures 172 in. long, 22 in. wide and 42 in. high, and it weighs 390 lb. Motive power can be supplied by foot pedals or a 1-hp electric motor.



how Vacuum Metals' FERROVAC boosts ball bearing screw life up to 400%...

Ball bearing screw assemblies, first used in automobile steering mechanisms, are now found in such critical applications as the actuation of landing gear and control surfaces of aircraft and guided missiles. And it was in tough jobs like these that the assemblies failed in fatigue. Then a leading manufacturer tried vacuum-melted FERROVAC® for the balls – and service life rose as much as 400% over the original life. Here's why . . .

Vacuum melting improves fatigue properties – It literally sucks gaseous impurities – focal points for fatigue failure – from the molten metal. Vacuum-melted metals are cleaner, purer, tougher. And cleanliness means an added bonus in fewer rejects.

Only Vacuum Metals gives you one-source service – Vacuum Metals Corporation, Division of Crucible Steel Company of America, provides a fully integrated service from melting and casting through mill rolling and nationwide distribution of finished mill products. And you can get not only small experimental lots, but now, thanks to our new 2500 lb. induction furnace – the nation's largest – you can also get large-scale continuous production quantities of vacuum-melted metals. If you have an application which these unique metals may improve, please write giving full details. *Vacuum Metals Corporation, Division of Crucible Steel Company of America, P. O. Box 977, Syracuse 1, New York.*

VMC®

VACUUM METALS CORPORATION

Division of Crucible Steel Company of America

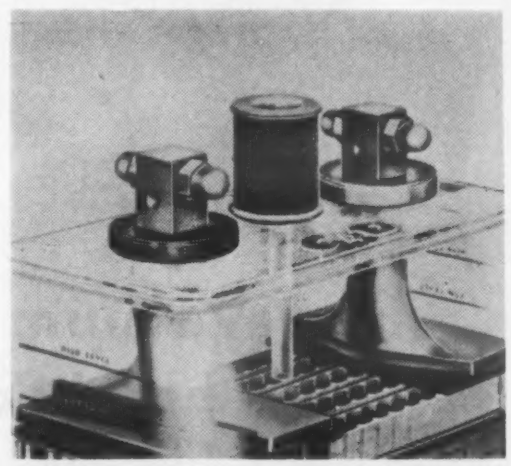
For more information, turn to Reader Service card, circle No. 456

For more information, turn to Reader Service card, circle No. 419

What's new IN MATERIALS

ing the steel in the temperature range of 1450 to 1540 F. It is available in 18 and 36-in. lengths and in widths from 1/64 to 14 in. It is recommended for dies, jigs, punches, templates, gages and small tools.

The other steel, an air hardening type, is a chromium alloy steel that is said to provide a high degree of wear resistance as well as a wide hardening range. A Rockwell C hardness of 65 may be achieved within a temperature range of 1700 to 1800 F. Tools made from this steel are said to be suitable for punching stainless steel, Monel and other abrasive metals. The air hardening type is available in 36-in. lengths in a wide range of widths and stock sizes.

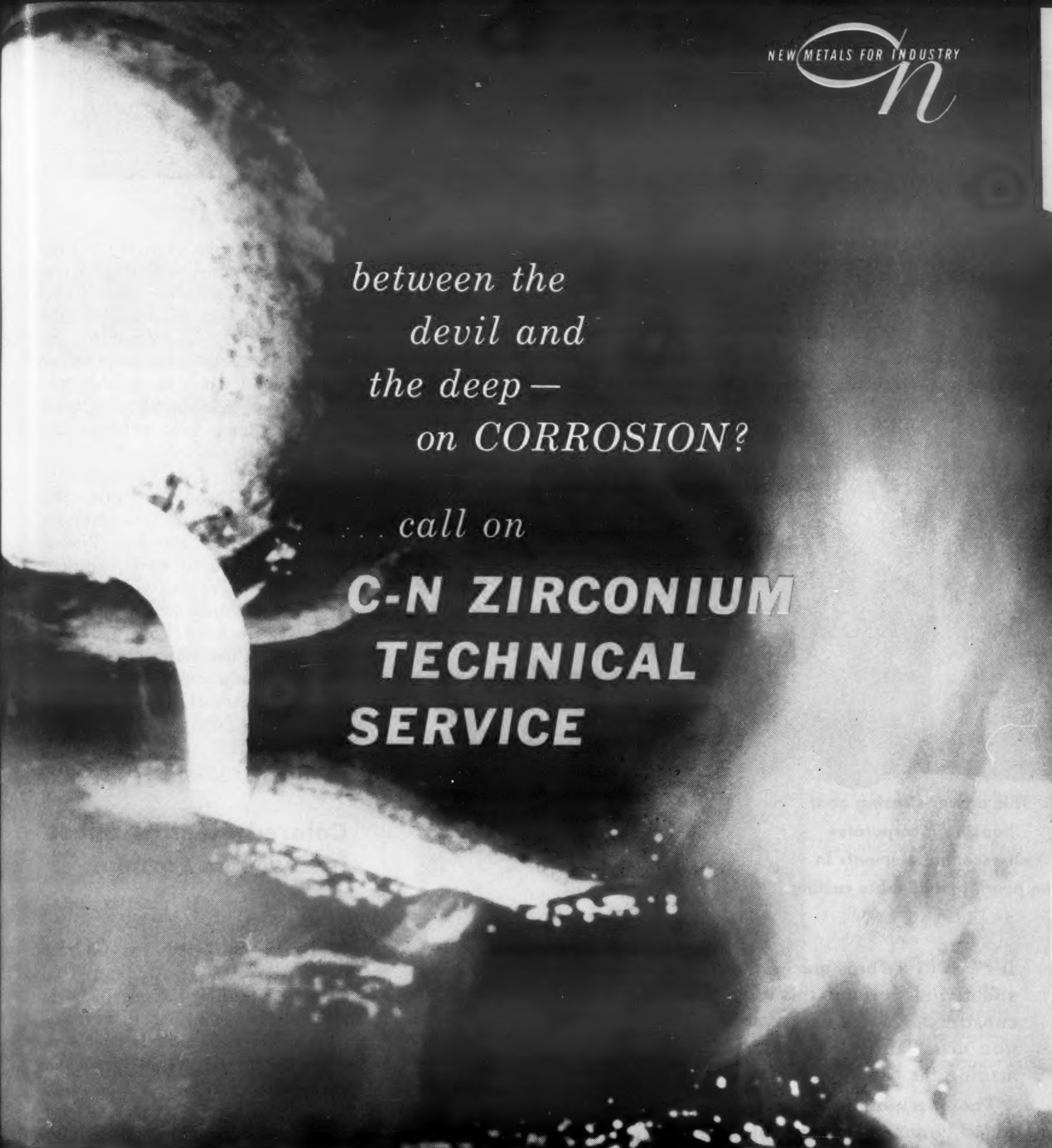


Safety vent *of porous material diffuses explosive gaseous mixtures escaping from telephone battery cell.*

Bonded Abrasives Check Explosive Gases

Vitrified bonded abrasive products are finding wide use as porous media for gas diffusion, liquid filtration and similar applications. An interesting application of bonded abrasives is the use of a fused, crystalline, aluminum oxide abrasive as a safety vent on a telephone battery cell. Explosive mixtures of hydrogen and oxygen gases, formed by the electrolization of water during charging, are

For more information, Circle No. 506 ➤



C-N/Zr Tech Digest

Corrosion Resistance of Zirconium in certain media

	Zirconium	Tantalum
Sodium hydroxide	Excellent in 10% to 50% NaOH from room temp. to 212°F.	Excellent in 5% NaOH @ 212°F. Poor in 40% NaOH @ 230°F.
Hydrochloric acid	Excellent in dilute HCl at all temps. In conc. HCl: Excellent at room temp. Poor at boiling pt.	Excellent in dilute and conc. HCl from room temp. to 212°F.
Potassium hydroxide	Excellent in 10% to 40% KOH from room temp. to 212°F.	Excellent in 5% KOH @ 212°F. Poor in 40% KOH @ 230°F.

Excellent: Less than 0.005 in. penetration per year
Poor: More than 0.010 in. penetration per year
Data from "Zirconium, Its Production and Properties" Bulletin 561, Bureau of Mines.

A new economical solution to many problems of corrosion is in the making — Columbia-National ZIRCONIUM. For example, unique zirconium properties include exceptional resistance to strong, hot alkalies and acids.

Large quantities of commercial-grade zirconium sponge are now available from Columbia-National's plant near Pensacola, Florida. Zirconium mill shapes are available from leading producers of alloy products.

Don't get stuck between the "devil and the deep"!

Columbia-National's engineering staff and research laboratories, with extensive experience in all aspects of metallurgy, will be your extra brainpower for investigating zirconium in relation to your specific problem — providing actual data for applying to your product or process. Write for data on properties, fabrication and corrosion resistance of zirconium.

Columbia-National Corporation

NEW METALS FOR INDUSTRY

Jointly owned by Columbia-Southern Chemical Corp. and National Research Corporation

DEPT. C-2B — 70 MEMORIAL DRIVE, CAMBRIDGE 42, MASSACHUSETTS

diffused through the vent at different rates to prevent an explosion; if allowed to pass freely from the battery cell, the hydrogen and oxygen gases would be extremely hazardous in the presence of an open flame or spark. The vent also prevents an accidental spark or flame from entering the battery cell.

Manufactured by Simonds Abrasive Co., Tacony & Fraley St., Philadelphia 37, Pa., the abrasive product, called Borolon Porous Media, is said to have excellent resistance to acids, with the exception of hydrofluoric acid, which dissolves the bond, and fair alkali resistance. The material possesses high thermal shock resistance and has a mechanical strength of approximately 3000 psi under transverse loading.

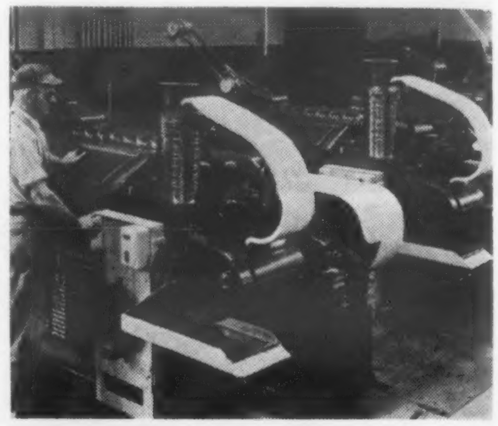
Colored Plastics Sheet for Vacuum Forming

A high impact plastics sheet material known as Crowl X-100 is being marketed by Charles Crowl Co., 11667 McBean Dr., El Monte, Calif., for use in postformed products. Based on Plio-Tuf, a modified, high impact styrene, copolymer resin produced by Goodyear Tire & Rubber Co., the sheets can be postformed by a variety of methods including, vacuum drawing, vacuum snapback, drape, plug and ring forming, blow molding and line bending. Crowl X-100 sheets are recommended for machine covers, advertising display panels, window frames, loudspeaker covers, refrigerator door liners and serving trays.

The sheets are available in standard thicknesses from 1/32 to 1/4 in. in sheet sizes of 39 x 71 in. untrimmed and 38 x 70 in. trimmed. Embossed in two textures, the sheets come in a variety of colors.

(more What's New on p 180)

For more information, Circle No. 446 ➤



***Fine wire** is spooled on these machines.*

Fine and Specialty Wire

Fine steel wire in sizes as small as 0.007 in. dia and shaped wire in sizes from 1/16 to 3/4 in. are now being produced by Bethlehem Steel Co.

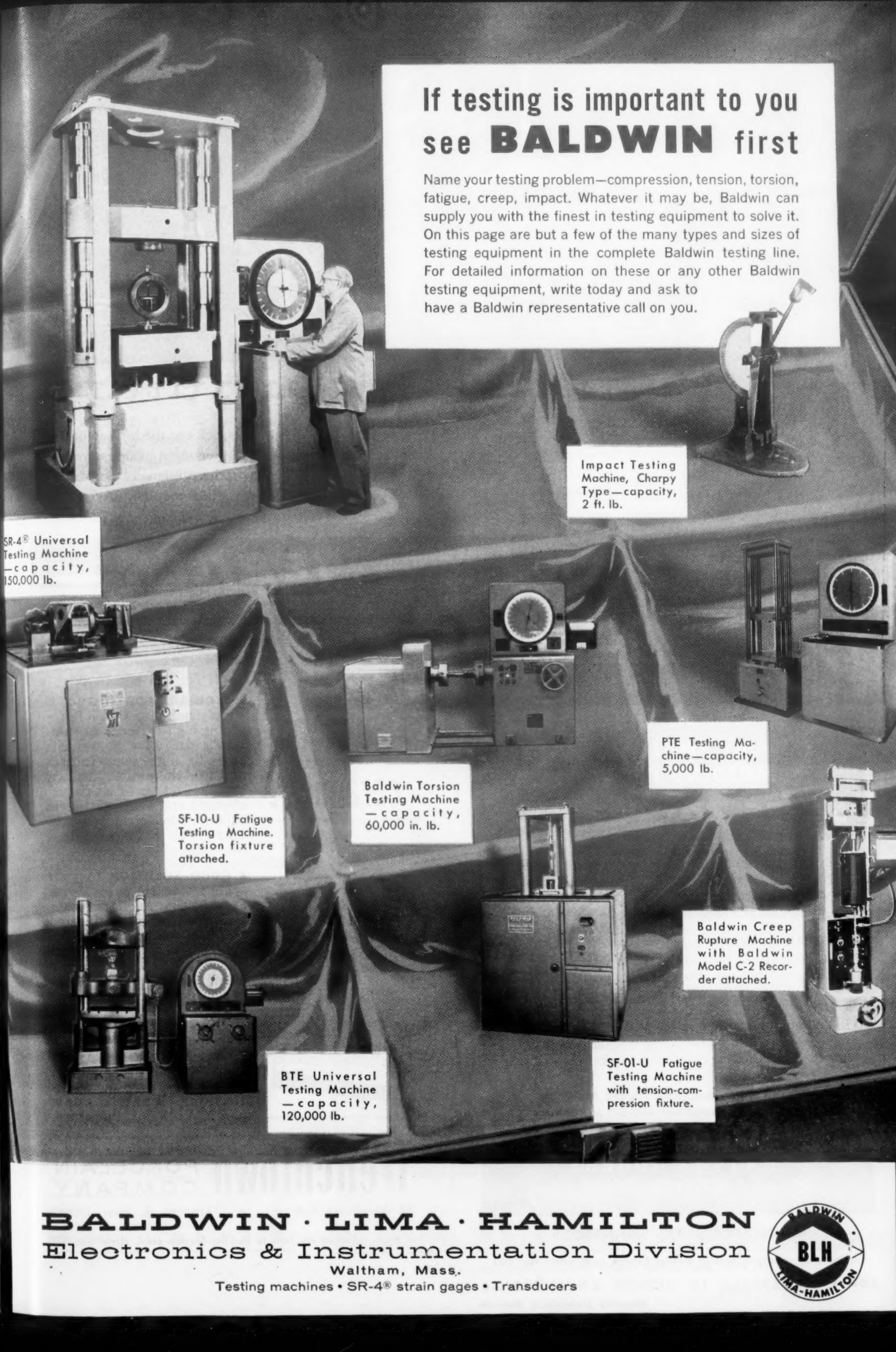
Fine wire is available with liquor, white liquor and coppered finishes, as well as electroplated with 99.9% pure zinc. Shaped wire is available in squares, flats, ovals, hexagons, octagons and D-shapes.

Fracture Properties of Aluminum Alloys

Low elongation aluminum alloys are currently being put to widespread use. However, though it is generally known that this type of material is notch sensitive and that, except for very mild stress concentrations, fracture starts at a free surface, specific information explaining these phenomena is not readily available.

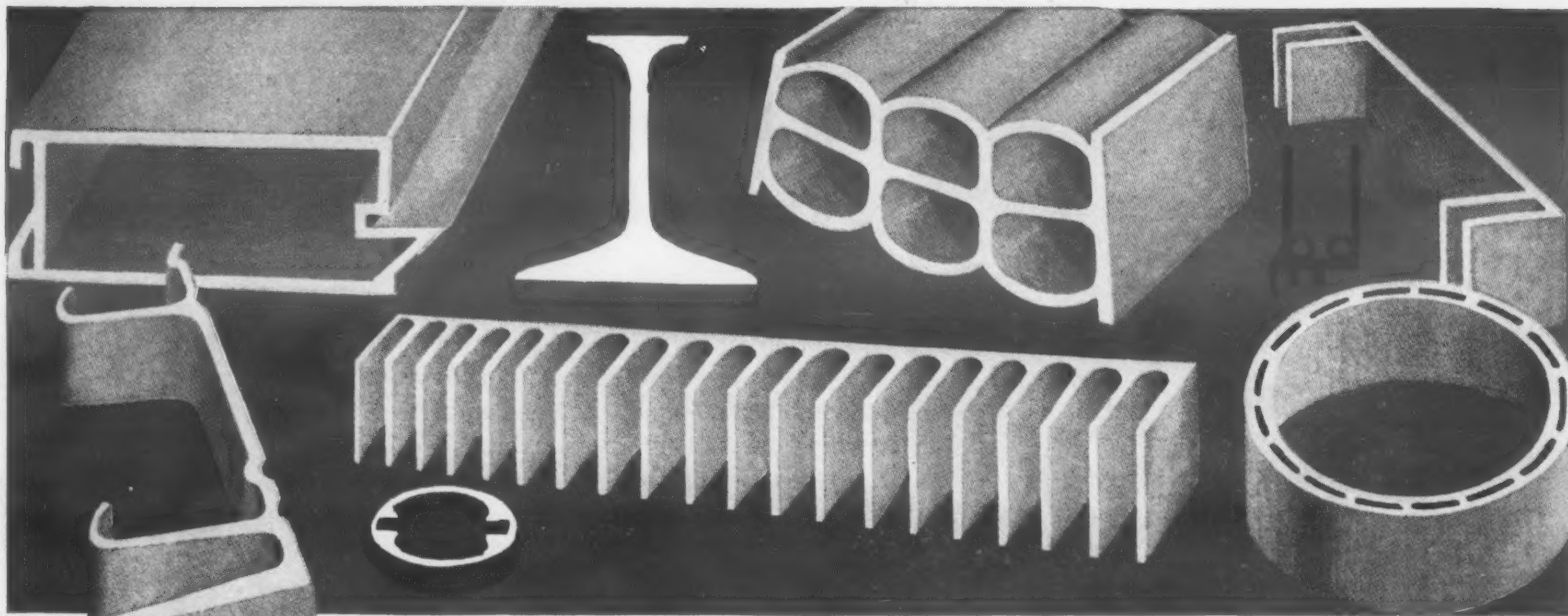
In order to supply some of this information, James A. Miller and Alfred L. Albert, National Bureau of Standards, performed tensile and bend tests on material in the T6 condition cut from 12 x 12 x 24-in. hand forgings of 2014 and 7075 aluminum alloys. Originally presented in *Technical Note* 3729 of the National Advisory Com-

For more information, Circle No. 511 ➤



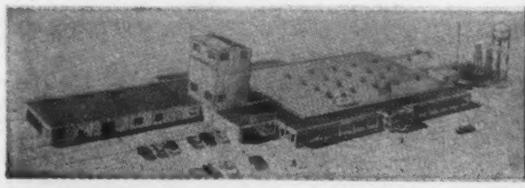
If testing is important to you see BALDWIN first
Name your testing problem—compression, tension, torsion, fatigue, creep, impact. Whatever it may be, Baldwin can supply you with the finest in testing equipment to solve it. On this page are but a few of the many types and sizes of testing equipment in the complete Baldwin testing line. For detailed information on these or any other Baldwin testing equipment, write today and ask to have a Baldwin representative call on you.
Impact Testing Machine, Charpy Type—capacity, 2 ft. lb.
SR-4® Universal Testing Machine —capacity, 150,000 lb.
PTE Testing Machine—capacity, 5,000 lb.
Baldwin Torsion Testing Machine —capacity, 60,000 in. lb.
SF-10-U Fatigue Testing Machine. Torsion fixture attached.
Baldwin Creep Rupture Machine with Baldwin Model C-2 Recorder attached.
BTE Universal Testing Machine —capacity, 120,000 lb.
SF-01-U Fatigue Testing Machine with tension-compression fixture.
BALDWIN · LIMA · HAMILTON
Electronics & Instrumentation Division
Waltham, Mass.
Testing machines • SR-4® strain gages • Transducers
BLH
BALDWIN LIMA-HAMILTON

For more information, turn to Reader Service card, circle No. 457

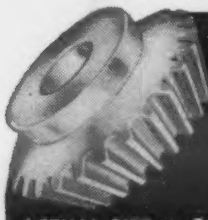


a part of your future

WERNER Aluminum EXTRUSIONS perform critical functions, achieve the high standards required for maximum product and production efficiency. Leading manufacturers of appliances, trailers, curtain walls, aircraft, etc. depend on WERNER EXTRUSIONS for precision tolerances, consistent quality control and delivery to meet their production schedule. If your present or future product requirements include extruded aluminum parts—contact WERNER Aluminum. *Sales representatives located in principal cities.*

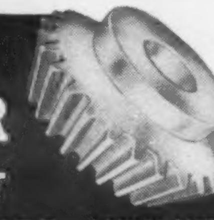


R. D. WERNER CO INC.
DEPT. MS-7 • GREENVILLE, PA. • PHONE: GREENVILLE 1600
ALUMINUM



Conversion to NYLON-GEAR BY SMALL-LOT MOLDING PROCESS

ACTUAL SIZE ACTUAL SIZE



SAVES 26¢ PER UNIT

This Zytel 101 Nylon Beveled Gear replaced a machined gear that formerly cost 59¢ each. After the initial tooling costs we die-molded it in one operation by our special injection process at 33¢ each.

COST ANALYSIS:

Tooling, set-up and first 100 pieces, including material and trimming......... **$286.00**

Additional 100 lots: $33.00

In addition to a cheaper piece price and equal wearing qualities, the Nylon Gear proved rustproof, noiseless, required no oiling and weighed less.

Let us quote on your Short-Run Plastic Moldings. We will gladly submit quotations without obligation.

DAYTON ROGERS
Manufacturing Company

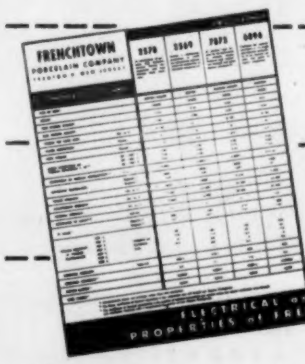
MINNEAPOLIS 7X, MINNESOTA

For more information, turn to Reader Service card, circle No. 441

engineered ceramics?

IF YOU ARE LOOKING for a supply source capable of providing high-performance materials that give you resistance to high temperatures and low thermal expansion; excellent mechanical strength and wear resistance; superior dielectric strength and both high and low frequencies—

A GOOD SOLUTION to your problem is to check with Frenchtown. As one of America's leaders in engineered ceramics for over 40 years, we are in a position to serve you in three ways: (1) providing research facilities for product improvement through *engineered* ceramics, (2) assisting in design and development work, (3) producing required parts and components in any quantity, to your most exacting specifications. Want to know more? Write for literature.



frenchtown PORCELAIN COMPANY

84 Muirhead Avenue | Trenton 9, New Jersey

For more information, turn to Reader Service card, circle No. 370

mittee for Aeronautics, the test results show that:

1. Stress and strain at failure vary with the location and the direction of the specimen in the forging, and there is no consistent relation between the values for specimens parallel to the direction of the length of the forging and the values for specimens in either transverse direction. This, together with the variability shown by specimens in the same direction, shows the need for adequate sampling in determining the properties of large forgings.

2. Use of the tensile strength of adjacent material for modulus of rupture in design results in conservative values for a) sound material with little residual stress if the critical stress pattern is uniaxial, or b) sound material with net elongation of 1% or greater if the critical stress pattern is biaxial.

3. The ratio of modulus of rupture to tensile strength for low elongation material increases with increase in strain at the beginning of failure.

Comparison of Plastics as Fuel Hose Liners

A pigmented epoxy resin containing an accelerator and a thinning agent of xylene and Cellosolve shows promise as a good, low cost material for relining fuel hoses. Gas sorbency tests of elastomers and plastics conducted recently at the New York Naval Shipyard by Joseph J. Steinmetz and E. C. Haas show

GAS SORBENCY OF HOSE

Solvent ➤ / Hose ▼	Absorption Time, Sec		
	Pentane	Benzol	Ethanol
Unlined	2400	900	300
Epoxy-Lined	15	50	20
Teflon-Lined	18	28	35

For more information, turn to Reader Service card, circle No. 427

that, out of a number of elastomers and plastics tested, epoxy resins and fluorocarbons (Teflon) have the best resistance to solvent vapors. The fluorocarbons show better solvent vapor resistance than the epoxies but are higher in cost. The epoxy resins, on the other hand, show good solvent vapor resistance, are readily available at relatively low cost, and can be used to reline present stocks of fuel hose with fairly simple relining methods.

In the tests run at the Naval Shipyard, various grades and types of natural and synthetic rubber and plastics hose liners were tested. The vapors of three solvents — pentane, benzol and ethyl alcohol (ethanol) — were used to evaluate the sorbency properties of the elastomers and plastics. Results of the sorbency tests conducted on epoxy and Teflon-lined hoses are shown in the accompanying table.

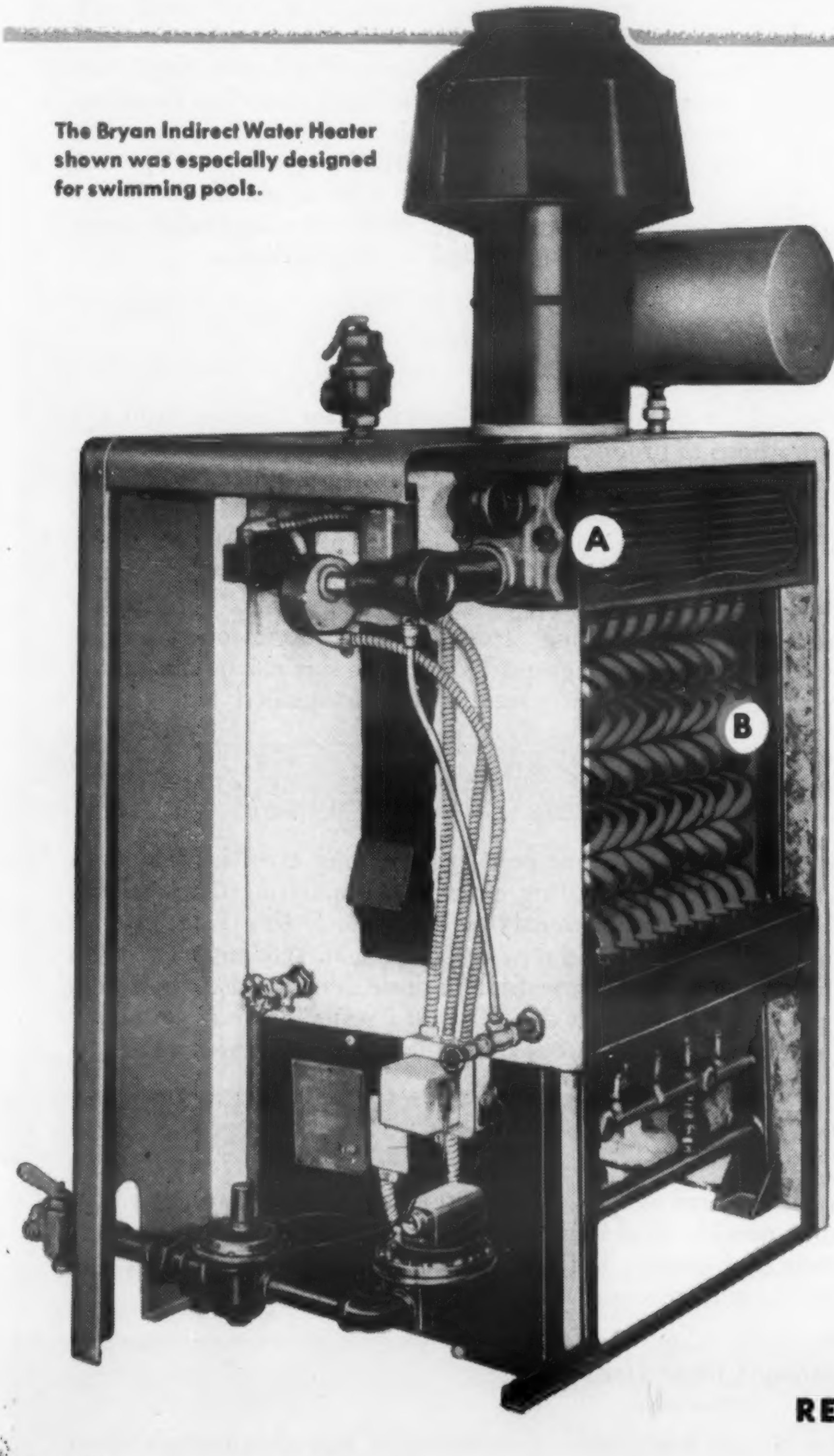
To test the durability of the epoxy lining, a thin-walled rubber tube was lined with the resin and bent sharply enough to kink the tubing and bend it flat. Some of the epoxy resin flaked off and could be blown out of the tubing. Outside of this treatment no further flaking was observed.

New Plastics Laminate for Cold Punching

A cold punching plastics laminate for printed circuitry has been developed by Richardson Co., 2747 Lake St., Melrose Park, Ill. Properties of the laminate, Insurok XT-896, permit it to be punched clean and sharp at average room temperatures. According to the producer, the material has low moisture absorption, low dielectric loss at high frequencies, and good insulation resistance. In copper-clad form it has high bond strength and good blister resistance.

"For maximum heat transfer and long service NOTHING CAN BEAT REVERE COPPER TUBE"

The Bryan Indirect Water Heater shown was especially designed for swimming pools.



says O. C. Skinner, President

BRYAN STEAM CORPORATION

Peru, Indiana

"Revere Copper Tube has been the big reason why our boilers have been so successful ever since we introduced them 30 years ago. Copper transfers heat more than five and a half times faster than cast iron or steel. Heat from the oil or gas-fired unit is transferred through the copper tubes to the water in the tubes in jig time and with a minimum of heat loss.

"It was because of the performance turned in by Revere Copper Tube in our boilers that it became the unquestionable choice for our new indirect heater which is engineered especially for swimming pools. In designing this heater we must credit Revere's Technical Advisory Service with an assist. For it was through their suggestions that we were able to produce a more efficient, longer-lasting heater at the least possible cost."

So when *you* buy a Revere Product, whether it be copper tube, brass strip or an aluminum extrusion, remember: Revere service does not end with the bill of lading. Why not call in Revere to "trouble-shoot" your problems?

REVERE COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

230 Park Avenue, New York 17, N. Y.

A This heat exchanger is made of heavy Revere Copper Tube with a bronze head bolted to the boiler shell. With this type of indirect heating flames cannot come in contact with the tubes carrying pool water. And since the temperature in this exchanger is below the critical point at which hardness scale readily forms, scale deposits are practically eliminated. This means longer heater life with higher heater efficiency.

B Boiler tubes of 3/4" and 1"-16 gauge seamless Revere Copper Tube act as primary heat exchanger between burner heat and boiler water. And, should it be necessary after long service, to replace the tubes, it can be done in a few minutes by anyone handy with tools.

In addition to the heater shown above Bryan also makes heaters and boilers in sizes from domestic types to 50 h. p. units for industrial uses. All use enduring Revere Copper Tube.

Mills: Rome, N.Y.; Baltimore, Md.; Chicago, Clinton and Joliet, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Brooklyn, N.Y.; Newport, Ark.; Ft. Calhoun, Neb. Sales Offices in Principal Cities, Distributors Everywhere.

For more information, turn to Reader Service card, circle No. 486

PRICES AND SUPPLY

The Outlook by Herman B. Director, *Consultant, Washington, D. C.*

Demand for stainless steel to increase

Production of stainless and heat resisting steel continues at a high level. In fact, first quarter production reports indicate that the only decrease occurred in the 400 series. Production of high nickel steels, as well as the 200 series 4% nickel steels, has actually increased. For example, consumption of stainless steel in the aircraft industry in 1954 amounted to 0.69 lb of stainless consumed for each pound of airframe weight produced. In 1956, 0.94 lb was used for each pound of airframe weight. This represents an increase of 36%.

The principal reasons for the drop in the price of scrap are: 1) the increased availability of primary nickel resulting from Government action to divert nickel to industry, and 2) advance shipments by International Nickel Co. (caused by the strike at the Huntington, W. Va., plant which has now been settled). Stainless steel demand and availability will both continue to increase during 1957, especially in view of reported earlier appearance dates for the 1958 automobiles. In spite of official denials, reports still persist that Chevrolet will introduce its 1958 model in August, 1957.

British purchase of bismuth to affect U. S.

Bismuth supplies, which are controlled by foreign producers, are subject to violent price fluctuations in the event demand increases to any large extent. The United Kingdom is reported to be purchasing bismuth for inventory for use in liquid form as a coolant in the British atomic energy program. Acquisition of supplies in any quantity by either the United States or the United Kingdom will pose real price problems, and U. S. consumers will be quickly affected.

Technological progress not restricted to metals

A principal speaker representing the Battelle Memorial Institute at the recent Design Engineers' meeting in New York City stated that "only through new developments in metallic materials can technological advances be made." In expanding these remarks, the speaker stated that metals nonexistent ten years ago, including titanium, zirconium, molybdenum, new alloys of aluminum, stainless steel, magnesium and nodular ductile iron, are in use today. Actually, the growth in plastics and ceramics in recent years is probably much more spectacular than that represented by metals. Certainly technological progress as represented by the plastics industry, virtually unknown ten years ago, and now in the 4-billion-lb-per-year production category, has had as much impact on technological advance as have metals.

Steel production to continue high

Even the more pessimistic steel producers are forecasting 1957 production at record levels. Consumers of most products will find it comparatively easy to meet their requirements with relatively short delivery times. Reaction to the price increases, which will undoubtedly result from wage increases after the first of July, has taken the form of a drop in order cancellations and requests for earlier delivery of July tonnages. We still stick with our forecast of a 7 to 9% price increase (MATERIALS & METHODS, Feb '57).

With increasing indications of an earlier model changeover in the automotive industry, third quarter steel production may not drop as low as industry sources had previously expected. Even with increased auto production, supplies are more than adequate and there should be no shortages. Lead times on heavy items, including structurals and plate, are also being cut back. Backlogs of structural fabricated steel orders are dropping with each successive month.

Substitute for mica needed

The Government has announced a new program designed to develop foreign sources of mica. Incentives offered include five purchase contracts as well as opportunities to deliver nonstrategic mica, along with strategic mica, in a package deal. This dependence

on mica, principally for electronic uses, offers a unique opportunity to U. S. industry. Development of an acceptable domestic substitute for these imports would meet with a ready and profitable market. Efforts at developing substitutes in the past have unfortunately resulted in successful substitutes for the most plentiful grades of nonstrategic mica rather than strategic grades, which remain in short supply.

Director on Barter Program

"In general the Barter Program seems to have resulted in a situation in which agricultural companies were forced into hiring metals experts and establishing metals departments while, conversely, metals producers were forced into the agricultural business. It seems obvious that neither is qualified to handle business entirely alien to its normal activities in order to accommodate the Government's program.

"The Barter Program is not over by any means. Even if the Government were to abandon its Barter Program, it would take a long time for world metal markets to recover from the impact of trade via barter. The scope of the Barter Program is best illustrated by considering that in fiscal year 1956 ten materials were involved for a total of $104.9 million, as compared with 15 materials in fiscal year 1957 for a total of $188.5 million.

"Basic tariff legislation was enacted in the period when prices were far lower than they are today. For example, lead was 6¢ a lb, as compared with 15½¢ today. The limits to which tariffs can be increased in order to restrict foreign imports are therefore very small, since maximum increases are geared to the lower prices of lead and zinc. Even if tariffs were increased to the maximum permissible, foreign products would simply absorb the tariff increase and continue to flow into the United States. We believe, therefore, that the most likely prospects are that 1) there will be token tariff increases followed by 2) imposition of import quotas. We should have learned a long time ago from our own agricultural subsidy program that domestic subsidies and tariff protection without import quotas normally result in nothing more than an increase in total world production and an increase in imports into the United States. Agricultural programs are protected by subsidies, tariffs and import quotas. This appears to be the only effective means of 'protecting' our minerals industries. As for the consumer, it means inflexible prices at a level higher than would otherwise prevail."

Zinc price drop to spur minerals program

As we had forecast (MATERIALS & METHODS, Jan '57), the suggestion of a cessation in Government buying of zinc and lead, plus suspension of the Barter Program, resulted in a sharp drop in the price of zinc and a drop in the price of lead. Consumers of galvanized products benefited directly from the drop in zinc prices since the prices of galvanized products were adjusted accordingly.

In announcing the suspension of barter activities, the Dept. of Agriculture stated that the objectives of the Barter Program did not appear to have been achieved, in that barter was being used as a substitute for dollar sales rather than as a means of increasing net exports.

The confusion in the zinc-lead purchase program is spurring efforts by the Administration to put before the Congress a long-range minerals program. This program is reported to include: sliding scale tariff, quota protection, stepped up research and development, grants, loans, additional tax benefits, transitional Government purchases, and market and price guarantees.

No real shortage of castor oil for plastics

The Government's recent report on the possible shortage of castor oil turns out, on careful inspection, to be purely statistical conjecture.

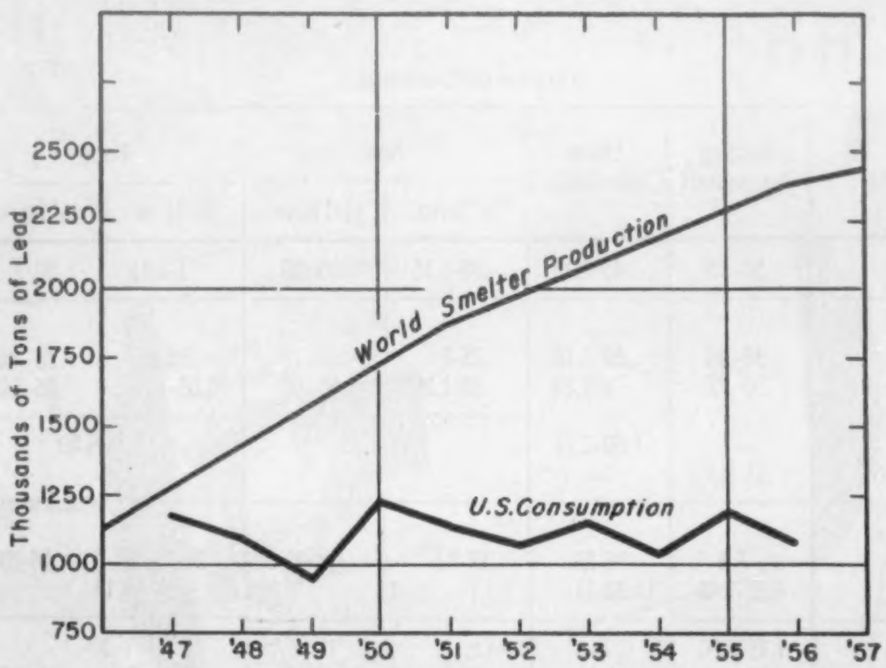
A new process for the manufacture of nylon for field wire coverings substitutes sebacic for adipic acid. Sebacic acid is derived from castor oil and if this new process should reach large scale commercial proportions, there would be a theoretical shortage of castor oil for sebacic acid needs several years hence. For the present, however, no immediate shortage is foreseen and castor oil supplies are more than adequate.

Urethane plastics foam expands

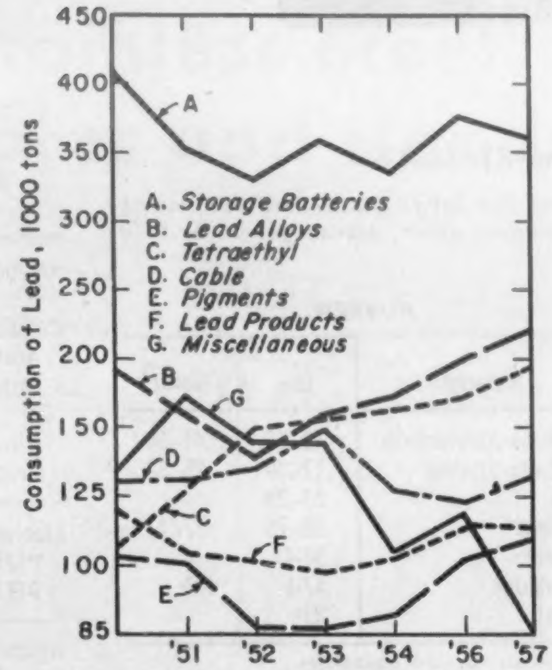
Urethane plastics foam, a comparatively new product, is threatening to unseat foam rubber as a padding material. Although only 10 million pounds were produced last year, indications are that before 1960 production will have increased by tenfold. Automatic production techniques recently developed are replacing hand batch processes.

Plastics lead in materials and products expansion

According to a Dept. of Commerce study of 288 selected products and services, 16 have expanded more than 40% since 1940. Interestingly enough, of the 16, six are either plastics materials or related to plastics. They include: polyethylene, various types of plastics pipe, styrene, butadiene, synthetic rubber and synthetic fibers (except rayon). Among the metals, only titanium is listed. Among manufactured products, the list includes power steering, power brakes, television receivers, and electric and gas dryers.



World smelter production *and U. S. consumption of lead over the last ten years.*



U. S. consumption *of lead by end use from 1951 to 1956.*

1957 Will See Increased Production, Consumption of Lead

■ World smelter production of lead in 1957 is expected to reach an all-time high of 2,328,000 short tons—an increase of 27,000 tons over production in 1956. The United States is expected to lead world production with about 550,000 tons. The second largest producer of lead is Australia, with an estimated production of 260,000 tons. The U.S.S.R. follows closely with an estimated production of 255,000 tons.

Consumption of lead since the end of World War II has fluctuated up and down in rhythm with increased and decreased business activity and varying degrees of international tension. On the average, however, consumption has increased significantly, and according to R. Hendricks, vice president of Consolidated Mining and Smelting Co. of Canada, Ltd., lead is presently being consumed at a greater rate than new reserves are being discovered. As a result, world reserves are being gradually depleted. On the other hand, Mr. Hendricks feels that "this situation could quickly reverse itself" if the research work now being carried out to develop gas turbine engines for passenger cars is successful. These engines will not require high octane fuel and if the market for tetraethyl lead is lost, "we could have a world surplus of lead."

At present, supplies of lead are adequate to meet all foreseeable demands. As far as prices are concerned, so long as the Government continues to buy domestic lead for the stockpile and maintains its barter program, there will be no further changes for some time. Should the Government discontinue these activities, the chances are that prices will decrease.

(Prices on p 190; more News on p 196)

WORLD SMELTER PRODUCTION OF LEAD (1000 short tons)

Country	1946	1956[a]	1957[a]
Argentina	18	20	22
Australia	154	263[b]	260
Austria	5	11	12
Belgium	26	113	110
Burma	—	16	16
Canada	166	148	156
China	—	19	19
France	35	70	70
French Morocco	—	31	30
Germany (East and West)	30	161	163
Italy	16	43	45
Japan	4	40	40
Mexico	152	214	220
Northern Rhodesia	9	17	18
Peru	40	62	66
Poland	12	24	24
Rumania	4	12	12
Spain	36	65	65
Sweden	12	23	23
Tunisia	8	27	27
USSR	53	255	255
United Kingdom	3	7	7
United States	338	542	550
Yugoslavia	36	83	83
Other[c]	8	35	35
Total	1167	2301	2328

[a]Estimated.
[b]Excludes bullion exported, probably 3000 tons.
[c]Brazil, Bulgaria, Czechoslovakia, Greece, Guatemala, Hungary, India, Korea, Netherlands, Portugal.
Source: U. S. Bureau of Mines.

PRICES AND SUPPLY

Prices of Materials

Changes since last month are bold faced

NONMETALLICS

Prices for large quantities for range of grades, color, sizes; given in $/lb

RUBBER

Material	Dry	Latex
Butadiene-Acrylonitrile	.49-.65	.44-.54
Butadiene-Styrene	.17-.30	.26-.32
Butyl	.23-.28	—
Neoprene[a]	.39-.75	.37-.47
Silicone[a]	1.90-4	—
Polysulfide[a]	.47-1	.70-.92
Natural	.33[b]	—

[a]Less than carload quantities.
[b]Average spot price for month of Apr.

GLASS FOR REINFORCED PLASTICS

Fabric ($/yd, 38 in. wide)[a]	
112 Woven	.48
181 Long-shaft satin weave	.03
143 Unidirectional	1.00
Roving[a]	
Continuous	.40
Continuous spun strand	.36
Continuous chopped spun	.38
Milled fibers (1/32-¼ in.)[a]	.45
Mat	
Chopped strand (2 in.)[a,b]	.52-.72
Surfacing ($/1000 sq ft)[c]	10-19
Continuous chopped strand (¼-2 in.)	.40

[a]Price includes binder or finish.
[b]Price varies with binder.
[c]0.010-0.020 in. thick

THERMOSETTING PLASTICS

Material	Molding Compounds	Laminating, Casting Resins
Alkyd	.34-.53	—
Epoxy	—	.45-.80
Melamine	.42-.45	.40-.41
Phenolic	.20-.40	.17-.34
Polyester	.42	.32-.50
Silicone	2.75-5.40	1.55-1.74[a]
Urea	.19-.33	—

[a]60% solids content.

All prices are approximate and given solely for general guidance of those responsible for materials selection.

THERMOPLASTICS

Material	Molding Compounds	Sheet (.030-.250 in.)	Rod		Tube	
			⅛-¼ in.	⅜-1¼ in.	⅛-¼ in.	⅜ 1¼ in.
Acrylic	.51-.59	.49-2.15	.90-1.15	.80-.90	1-1.15	.90-1
Cellulosic						
Acetate	.36-.65	.92-1.16	.75-1	.65-.75	.85-1	.75-.85
Butyrate	.50-.72	1-1.28	.95-1.20	.85-.95	1.05-1.20	.85-1.05
Nitrate	—	1.60-2.73	1.45-1.75		2.25-5.00	
Propionate	.51-.63	—	—		—	
Fluorocarbon						
PTFCE	7-8	15-23	18-22	14-20	20-22.50	16-20
PTFE	4.50-7.45	14.30-11	13		13	
Nylon	1.35-2.30	—	3		3	
Polyethylene	.37-.56	.85-1	.75-1	.65-.75	.85-1	.75-.85
Polystyrene	.27-.44	.57-.61	.65-.90	.55-.65	.75-.90	.65-.75
Vinyl	.27-.43	.62-.92	.75-1	.65-.75	.85-1	.75-.85

NONFERROUS METALS

Mill base prices for large quantities; given in $/lb except where indicated

ALUMINUM

Pig (99-99.9%)	.25-.27
Ingot (99-99.9%)	.27-.29
Foil (5-0.5 mil)	.55-.77
Alloy Ingot (13, 43, A132, 214)	.29-.32
Sheet (1100, 3003; 3-.03 in.)[a]	.40-.45
Plate (1100, 3003, 5050, 3004, 5052)[a]	.40-.43

[a]Mill finish.

BRASS

Form	Cart., 70%	Low, 80%	Red, 85%
Sheet, Strip	.47	.50	.51
Seamless Tubing	.50	.53	.54
Rod (not f.c.)	.47	.50	.51
Wire	.48	.51	.52

COPPER

Ingot (elec)	.32
Sheet, Strip (hot rolled)	.54
Seamless Tubing	.54
Rod, Drawn	.51
Rod, Free Cutting	.60
Wire	
Round	.37
Square, Rectangular	.41
Magnet	.45

LEAD

Common Grade	.15½

MAGNESIUM

Pig (98.8%)	.36
Ingot (98.8%)	.37
AZ91B Ingot (die casting)	.37
AZ91C Ingot (sand casting)	.41[a]

[a]Delivered price.

NICKEL

Form	"F"	"A"	Monel
Ingot	.75[a]	—	—
Rod	—	1.07	.89
Sheet, C.R	—	1.26	1.06
Strip, C.R.	—	1.24	1.08
Seamless Tube	—	1.57	1.29

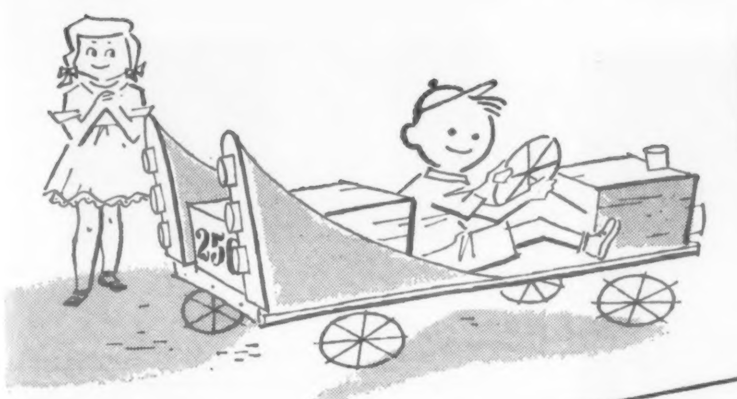
[a]Delivered price.

TIN

Primary[a]	.98-.99

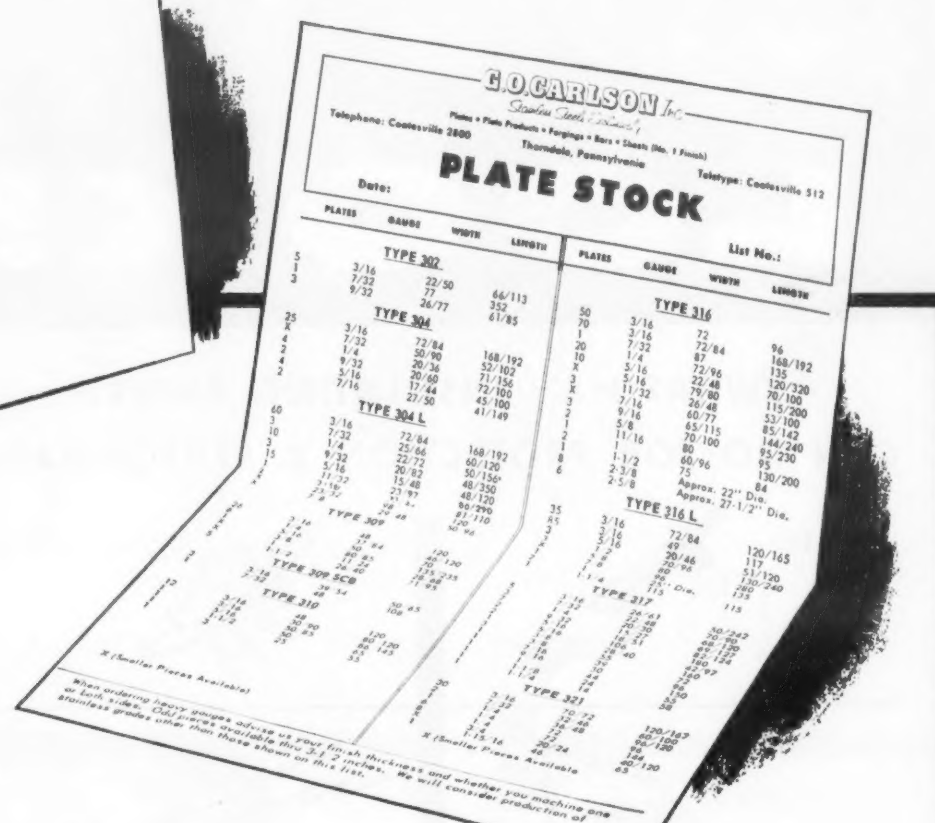
[a]Delivered price.

(continued on p 192)



Keep up to date...

on Stainless Steel Plates and Heads



Carlson's Weekly Stock Lists tell you what you want to know:

- the Type, Gauge, Width and Length of stainless steel plates in stock.
- the Type, Gauge and Size of stainless steel heads in stock.
- the sales representatives and warehouse distributors in this country and Canada who are ready to serve you.

YOU can save time by checking these weekly stock lists. Here is an up-to-the-minute report on our large, diversified stock of stainless steel plates and heads that have been produced especially for chemical industry applications.

Carlson plates in Types 304-L, 316-L and 317-L are more and more in demand. Substantial stocks of these extra-low-carbon grades, along with other chromium-nickel Types 302, 304, 309, 309-S, 310, 316, 317, 321, 347 and 348 are available. Chromium grades 405, 410, 430 and 502-½% Mo are always in stock. Two precipitation-hardening grades, Types 17-4 PH* and 17-7 PH*—new plate grades that combine ease of fabrication, hardenability, high strength and corrosion resistance—are now in production and limited stocks are carried. To complete the story, stainless steel heads in Types 304, 304-L, 316 and 316-L are also stocked and can be shipped in a few days.

Make Carlson your *one-stop* source for that complete bill of material—stainless steel plates, heads, rings, circles, flanges, forgings, bars and sheets (No. 1 Finish).

When you need stainless plate . . .
Carlson gives you what you want when you want it!

*Trade Mark of ARMCO STEEL CORPORATION

G. O. CARLSON, INC.
126 Marshalton Road
Thorndale, Pennsylvania

Write for your copies of Carlson's Weekly Stock Lists . . . use this convenient coupon.

Name: . . . .

Company: . . . .

Address: . . . .

City: . . . . State: . . . .

G.O.CARLSON Inc.
Stainless Steels Exclusively
THORNDALE · PENNSYLVANIA
District Sales Offices in Principal Cities

For more information, turn to Reader Service card, circle No. 425

PRICES AND SUPPLY

TITANIUM

Sponge (99.3+%)	2.50-2.75
Bars, Rod	7.10-7.35
Plate	9.25-11.25
Sheet, Strip	11.40-12.10
Wire	8.50-9.00

ZINC

Primary[a]	.11-.12
Die Casting Alloys[b]	.16-.17
Sheet	.24
Ribbon	.22

[a]Prime Western—Special High Grade.
[b]Alloys 2, 3, 5. [c]Delivered price.

METAL POWDERS

Aluminum [a,b]	.36
Brass[a]	.37-.47
Copper (elec or red.)[a]	.46
Columbium	120
Molybdenum (98%)	3.80-4.10
Tantalum	49
Tungsten (C-red. 98.8%; H_2-red. 99+%)	4-5[c]
Zirconium	
Flash Grade	11.50
Electronics Grade	15

[a]Price for —100 mesh. [c]Delivered price.
[b]Freight allowed.

OTHER NONFERROUS METALS

Cadmium (bars)	1.70
Gold	$35/troy oz
Indium (99.97+%)	$2.25/troy oz
Manganese (99.9%)	.34[a]
Palladium	$23-24/troy oz
Platinum	$92-95/troy oz
Silver	91¢/troy oz
Tantalum (sheet, rod)	55-60
Vanadium	3.45
Zirconium (sheet, strip, bar)	27-35

[a]Delivered price.

IRONS AND STEELS

Mill base prices for large quantities

SEMIFINISHED STEEL ($/net ton)

Ingots, Alloy	74
Billets, Blooms, Slabs	
Carbon, Re-rolling	74
Carbon, Forging	92
Alloy, Forging	107
Seamless Tube Rounds	112
Wire Rods	$5.85/cwt

(continued on p 194)

PRICES AND SUPPLY

FINISHED STEEL ($/cwt)

Form	Carbon	High Str Low Alloy	Alloy
Plate	4.85	7.25	6.85
Sheet, H.R.	4.67	6.90	—
Sheet, C.R.	5.75	8.52	—
Strip, H.R.	4.67	6.95	7.75
Strip, C.R.	6.85	10	14.55
Bar, H.R.	5.07	7.42	6.12
Bar, C.F.	6.85	—	8.32

STAINLESS STEELS ($/lb)

Material	Forging Billets	H. R. Bars	Plate[b]	Sheet, Strip
Austenitic				
301, 302, 302B, 303, 304, 305	.36-.40	.41-.46	.45-.49	.50-.56
321[a]	.45	.53	.58	.63
347[a]	.54	.62	.67	.76
Martensitic				
410[a]	.27	.33	.34	.39
416	.28	.33	.35	.47
403	.31	.36	.39	.47
420, 440	.33	.40	.44	.60
Ferritic				
405, 430, 430F[a]	28-.29	.33-.34	.35-.36	39-.50
442	.32	.38	.40	.54
431	.36	.43	.44	.54
446	.38	45	.46	.67
High Mn				
202[a]	.35	.41	.43	.47
Extra Low C				
304L	.47	.54	.56	61
316L	.64	.74	.78	.82
Precip Hard.				
17-7PH	.55	.65	.72	.77-.82

[a]**Ingot prices approx 60% of forging billet price.**

METAL POWDERS ($/lb)[a]

Sponge Iron	.09-.10
Electrolytic Iron	
Annealed (99.5%)	.37
Unannealed (99+%)	.34
Stainless Steel	
304	1.05
316	1.44

[a]Price for —100 mesh.

IRON ($/gross ton)

Pig	64.50-65.50

(continued on p 196)

PRICES AND SUPPLY

TIN PLATE ($/base box)

Hot Dip (1.25-1.50 lb)	10.05-10.30
Electrolytic (0.25-0.75 lb)	8.75-9.40
Black Plate	7.85-7.95

FINISHES AND COATINGS

ORGANIC COATINGS

Material	Avg Thk per Coat, mil	Mils Required[a]	Cost, ¢/sq ft/dry mil[b]
VARNISHES, ENAMELS			
Short Oil Phenolic			
Varnish	1.0	1.0	1.50
Enamel	1.2	1.0	1.75
100% Phenolic	1.0	1.5	1.75
Straight Oil-Modified			
Alkyd	1.5	1.5	1.50
Alkyd-Amine (90-10)	1.5	1.5	1.75
Alkyd-Phenolic (50-50)	1.5	1.5	1.75
Alkyd-Vinyl (50-50)	1.0	2.0	2.0
Alkyd-Styrene (70-30)	1.2	1.5	1.75
Epoxy	1.8	1.8	2.00
Silicone	.5-1.0	.5-1.0	6.0
Furane	2.0	2.0	1.0
Neoprene	5.0	5.0	1.50
DISPERSION COATINGS			
Phenolic	1.0	1.5	1.75
Vinyl	1.0	2.0	2.50
Fluorocarbon	1.0	1.0	15.0
LACQUERS			
Nitrocellulose	1.0	2.0	2.50
Vinyl	1.0	2.0	2.50
Acrylic	1.0	2.0	2.75

[a]Thickness over phosphate coating required for exterior durability on steel. For purely decorative coating, 1 mil will usually suffice.
[b]Materials cost only. Realistic price comparison can be made only on basis of dry applied coating, not on basis of cost per gallon.

Stainless Use in Autos Continually Increasing

Results of a nationwide survey of automobile owners reveal that consumers are willing to pay a premium for stainless steel trim.

Endorsement of stainless steel as superior to all other materials being used for trim came in answer to the question: "What

USE OF STAINLESS STEEL ON A TYPICAL 1957 CAR[a]

Parts	Number of Pieces	Weight, lb
Body Moldings	19	6.5248
Headlamps	2	0.2766
Window Moldings	25	11.7160
Windshield Wipers	9	0.2318
Wheel Covers	4	5.4112
Ornaments	21	1.1600
Carburetor	5	0.0173
Locks and Switches	10	0.0550
Exhaust Valves	8	1.6144
Clock	4	0.0042
Controls	6	0.0806
Miscellaneous	42	1.2069
Totals	155	28.2988

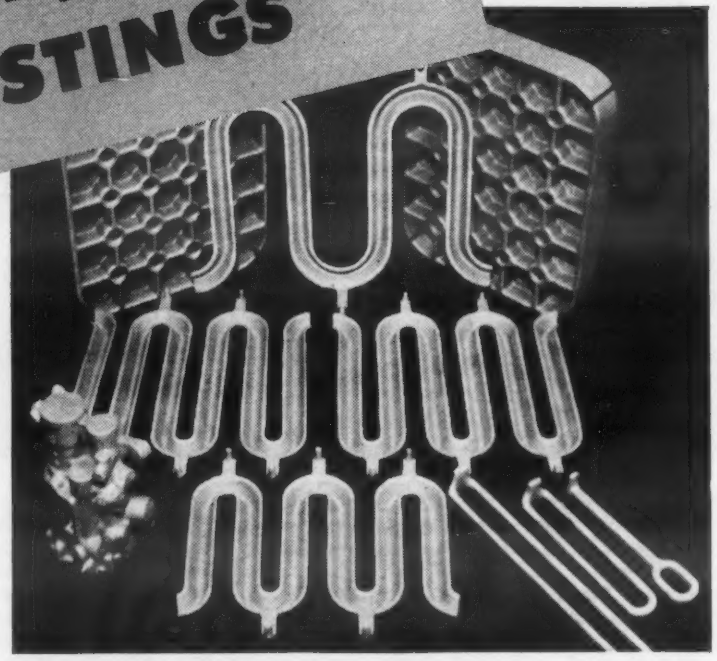
[a]Medium priced.

one material, in your opinion, is best for auto trim?" Stainless steel was named by 57% of all those interviewed. To the question "Would you pay a premium price to have all trim on your next car made of the material named best?" 40.1% answered yes.

Commenting on these results, Richard E. Paret, of the Committee of Stainless Steel Producers, said, "This survey has confirmed our belief that the average car owner prefers stainless steel for bright work. It also shows that an overwhelming majority of car owners prefer to see the amount of bright work on cars remain at least the same or even increase."

Whether or not the results of this survey have influenced producers is difficult to determine. Nevertheless, according to the Committee of Stainless Steel Producers, American Iron and Steel Institute, automotive producers have increased the use of stainless steel on 1957 models by 20% or more. Among the "low price three," an average of 24.3 lb of stainless is used, as compared to 20.0 lb last year. In the higher priced cars, the amount of stainless steel used has increased by as much as 75 lb per car. On a typical 1957 car the number of stainless steel parts may total 100 or

For more information, turn to Reader Service card, circle No. 449



more (see accompanying chart).

The automotive industry is presently the largest consumer of stainless steel (see MATERIALS & METHODS, June '57, p 240). Last year it used over 100,000 tons, and in 1957 it should require considerably more. However, one question remains to be answered: The automobile consumers sampled in the survey indicated that they would be willing to pay more for cars with stainless steel trim and auto producers have used more stainless trim. Only time will tell whether consumers will actually be willing to pay the premium.

What's Happening in Prices and Supply

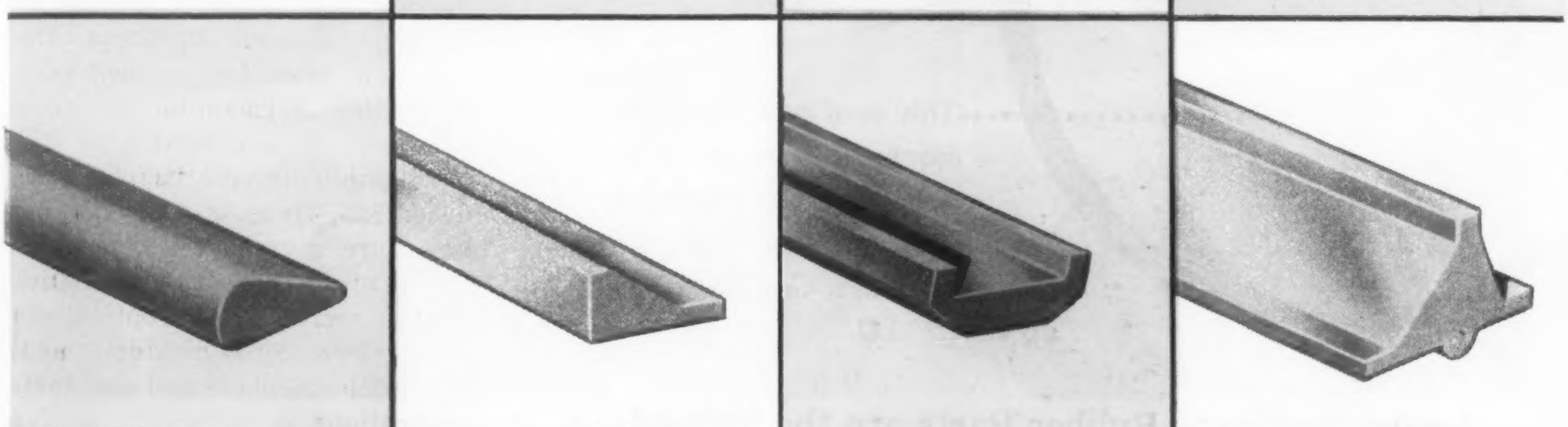
Melamine & urea—Barrett Div., Allied Chemical & Dye Corp., will double melamine and urea molding compound production at its Toledo facilities. Scheduled for completion by mid-1959, the expansion will make the Toledo facilities the largest thermosetting resins plant in the country.

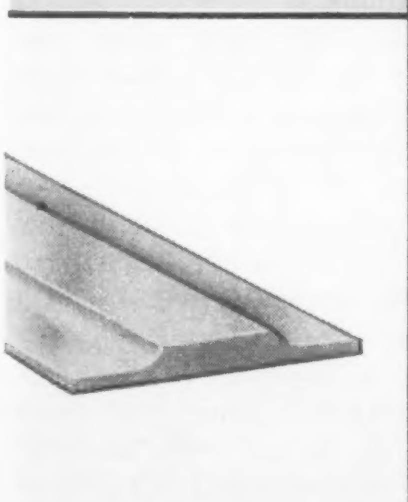
Steel—The American steel industry, which has added over 41 million tons to its production capacity since World War II, will need to add another 50 million tons in the next 18 years, according to Roger M. Blough, chairman of the board, U. S. Steel Corp. Between now and 1975, Mr. Blough says, U. S. Steel Corp. will have to increase its capacity by 1 million tons each year.

Zinc—The price of slab zinc has been cut to 12¢ per lb. This is the first change in slab zinc price since January, 1956, when the previous 13½¢ per lb price was established. Prices of zinc-base die casting alloy ingots have also been reduced 1½¢ a lb, making the price for the No. 3 alloy 16¢, No. 5 alloy 16½¢, and No. 2 alloy 17¢ per lb. Reasons for the cuts are believed to be: 1) the recent

CONTOUR ROLLING

Close Tolerances That Require No Finishing



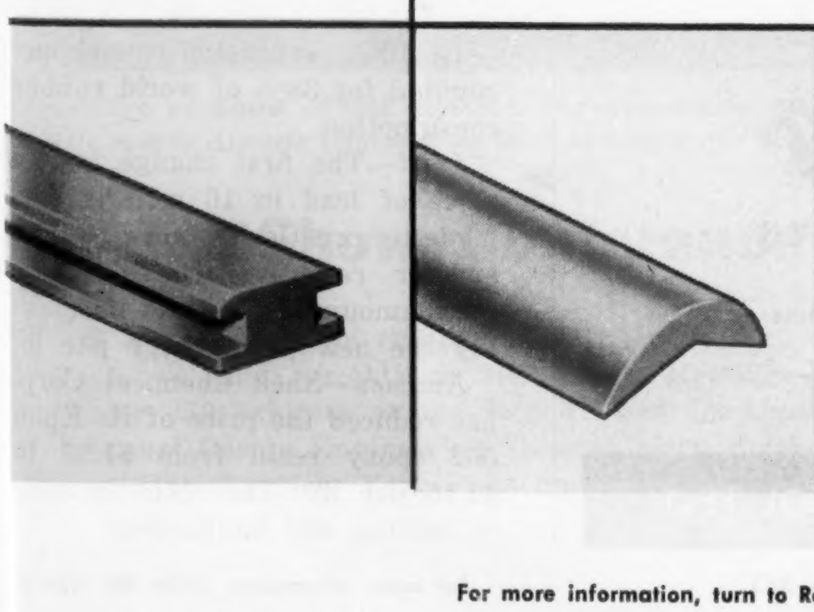


MAKEPEACE unique contour rolling process produces shapes held to tolerances as close as ± .001 of an inch.

Intricate angles of radii can be rolled into rod, wire, tubing and sheet.

MAKEPEACE unique contour rolling produces formed stock with excellent physicals and a fine finish that does not require a final finishing operation.

Send for the MAKEPEACE mill products booklet. It contains much information of value covering a wide range of Form Rolled Stock.



MAKEPEACE **FORM ROLLED STOCK**

D. E. MAKEPEACE COMPANY

Division of Union Plate and Wire Co.

ATTLEBORO, MASS.

ENGELHARD INDUSTRIES

For more information, turn to Reader Service card, circle No. 503

For more information, turn to Reader Service card, circle No. 363

suspension of the zinc bartering program by the Dept. of Agriculture, followed by uncertainty as to just when barter deals might be resumed and 2) recent warnings, by both the Assistant Secretary of the Dept. of Interior and Gordon Gray, of the Office of Defense Mobilization, to the effect that stockpiling of domestic origin zinc will be continued only "a while" longer.

Germanium — Reductions of about 10% in the prices of pure germanium metal and germanium dioxide were effected recently by Sylvania Electric Products, Inc. The new price for purified polycrystalline germanium metal is \$435 per kg, a reduction of \$50. Germanium dioxide has been reduced \$25, from \$275 to \$250 per kg. Pure germanium is used in the manufacture of transistors, diodes, rectifiers and optical devices. Germanium dioxide is used in special phosphors and electronic applications.

Rubber—By 1965, more than half of the world's rubber needs will be filled by synthetic rubber, according to W. S. Richardson, president, B. F. Goodrich Co.

Mr. Richardson predicts that total rubber consumption will expand by approximately 5% per year for the next decade, but production of natural rubber cannot be increased by more than 2½% annually. As a result, synthetic rubber output must be stepped up to meet rising demands.

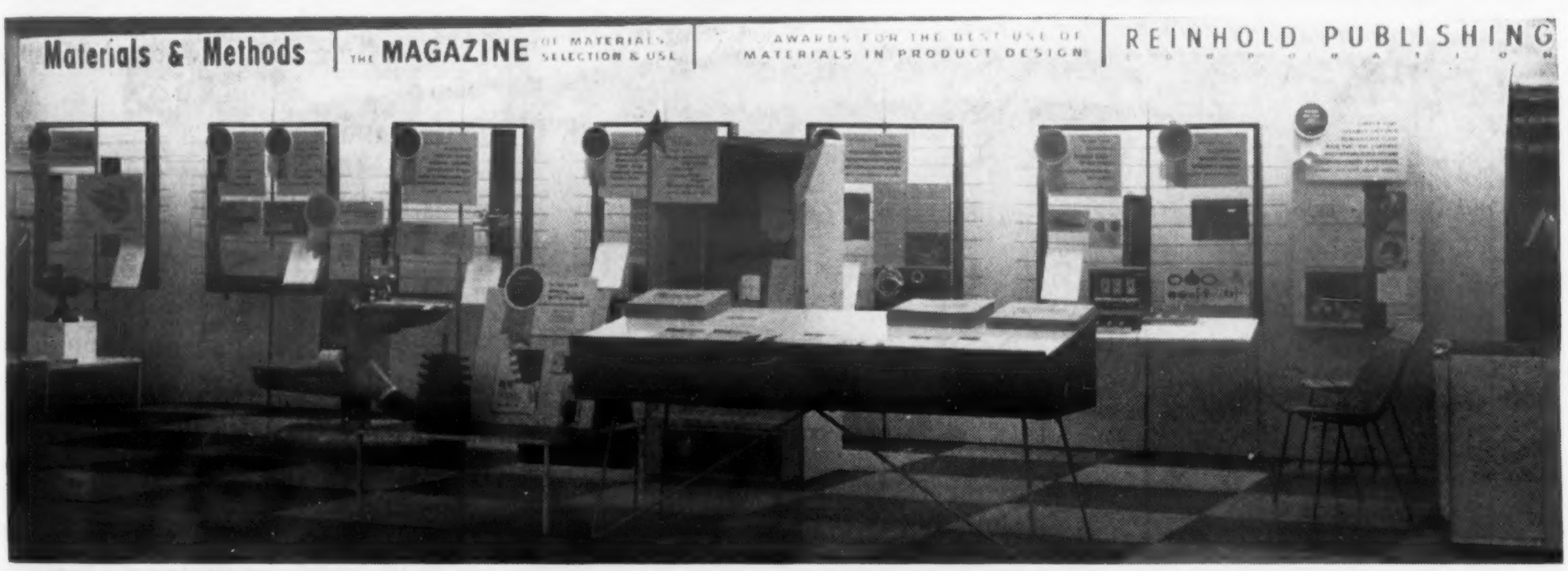
In 1956, synthetic rubber accounted for 38% of world rubber consumption.

Lead—The first change in the price of lead in 16 months was made by practically every custom smelter recently. The drop in price amounts to ½¢ per lb, making the new price 15½¢ per lb.

Epoxies—Shell Chemical Corp. has reduced the price of its Epon 562 epoxy resin from \$1.55 to \$1.15 per lb. The resin is used in casting and laminating.

For more information, Circle No. 526 ➤

News OF INDUSTRY



***Displays at Show** offered engineers the opportunity to examine new materials (top). Winning entries in this magazine's recent Awards Competition were shown in our booth (bottom).*

Design Show, Conference Attract Large Crowd

■ More than 18,000 engineers, designers and executives visited over 350 exhibits at the second annual Design Engineering Show held at the New York Coliseum in the latter part of May.

Exhibits at the show included an inestimable number of materials, finishes, parts and components that go into the making of end products. Many booths featured actual demonstrations of the operation of equipment and use of materials in product design. Hundreds of new products, some

News OF INDUSTRY

still in the experimental stage, were shown to give designers ideas they could incorporate into models still in the planning stage.

The Design Engineering Conference, sponsored by the Machine Design Div. of the American Society of Mechanical Engineers and held in conjunction with the Design Show, covered the use and development of new materials, new uses for old materials, new processes to improve materials, and design factors involved in the production and use of components and equipment. Over 1700 people registered for the Conference.

The four principal speakers at the materials sessions were: Charles R. Simcoe, metallurgical engineer, Battelle Memorial Institute; John H. Koenig, director and professor, School of Ceramics, Rutgers University; Wyman Goss, manager, Phenolics Engineering, General Electric Co.; and H. J. Reindl, supervisor, Research and Development — Finishes Section, Inland Mfg. Div., General Motors Corp.

The papers

Mr. Simcoe discussed technological advances being made in the use of titanium, zirconium, molybdenum, precipitation-hardened stainless steel, new alloys of aluminum and magnesium, nodular iron, etc. He covered such new metals as the titanium-6 aluminum-4% vanadium alloy.

John H. Koenig pointed out many recent developments in the field of glass, including new processes and treatments, new types and uses for glass (devitrified glass), centrifugal casting, conducting and reflecting coatings, fused seals, and electroluminescence. He also discussed new developments in cermets, ceramics and high temperature refractories.

Wyman Goss summarized "the complexity of plastics products available to the designer today." He covered many of the design factors involved in specifying

most of the plastics materials presently being used.

H. J. Reindl described the major factors determining the selection of specific finishes for specific applications. He described in detail the three general categories of finishes: organic coatings, metallic coatings and conversion coatings.

In general, both the Show and Conference were extremely successful in terms of number of people attending and information available. The Third Annual Design Engineering Show and Conference has been scheduled for April, 1958, in Chicago.

Investment Casting Data Published by Institute

The first industry-wide engineering and design manual on the investment casting process has recently been issued by the Investment Casting Institute. The significance of the publication, aside from the fact that it represents industry-wide agreement on the specification of dimensional tolerances, is that it demonstrates the value that can be derived from technical or trade organizations. The institute spent two years working out the information presented in the manual.

The design information in the manual covers surface finish and dimensional tolerances. Described under dimensional tolerances are the following: general tolerances, radii, straightness, flatness, concentricity, roundness, angle, length, parallel sections, blind and throughgoing cores, threads and airfoil contours.

In addition to the design section, the manual contains complete metal specifications and test bar standards for all standard investment casting alloys. Other sections of the manual cover the history and description of the investment casting process, includ-

For more information, circle No. 453 ➤

For more information, turn to Reader Service card, circle No. 431

For more information, turn to Reader Service card, circle No. 487

ing the lost wax and frozen mercury types; the objectives of the Investment Casting Institute; and a large number of case histories showing types and parts suitable for investment casting.

The "Investment Casting Engineering and Design Manual" is available from the Investment Casting Institute, 27 East Monroe St., Chicago 3, at $5.00 per copy.

Gamma Radiation Runs Titanium Furnace

Atomic radiation, in the form of highly energetic gamma rays from radioactive cobalt, has been put to a new and important use by Westinghouse Research Laboratories.

The gamma rays, according to Dr. Daniel Alpert, associate director, are being employed to detect and control the level of molten titanium in a new "cold hearth" arc furnace designed to prepare the purified titanium metal.

To carry out their new assignment the penetrating gamma rays pass through as much as 15 in. of solid metal. "The successful operation of this new titanium furnace," Dr. Alpert says, "demands exact control of the molten surface of the titanium ingot inside it. Such control must be foolproof, precise and fast working — yet must be accomplished under extremely difficult conditions. For example, the temperature of the white-hot liquid titanium is more than 3000 F."

By beaming the gamma rays through the walls of the furnace and the 12-in. titanium ingot inside it, engineers are able to "see" the actual level of the titanium. This information is used automatically to raise or lower the ingot to its correct operating level, thereby insuring proper operation of the furnace.

The source of gamma rays, a small needle of cobalt 60, is placed

For more information, turn to Reader Service card, circle No. 443

outside the furnace and in line with the top surface of the ingot. The "hot" cobalt 60 is kept inside a shielded lead box having walls about 4 in. thick. If the ingot inside the furnace is too high, it partly blocks the beam of gamma rays, reducing the amount of radiation getting through the furnace. If the ingot is too low, the beam is interrupted less and the amount of radiation through the furnace is greater. These changes in the amount of gamma radiation are used to detect and correct the level of the ingot.

The gamma rays passing through the furnace are detected by means of two scintillation counters. Each counter contains a crystal that changes the gamma rays into flashes of light. The counter then converts the light flashes into electrical pulses and amplifies them. These amplified pulses are fed to electronic circuits that are designed to drive a hydraulic system that raises or lowers the titanium ingot to the exact position required for proper operation of the arc furnace.

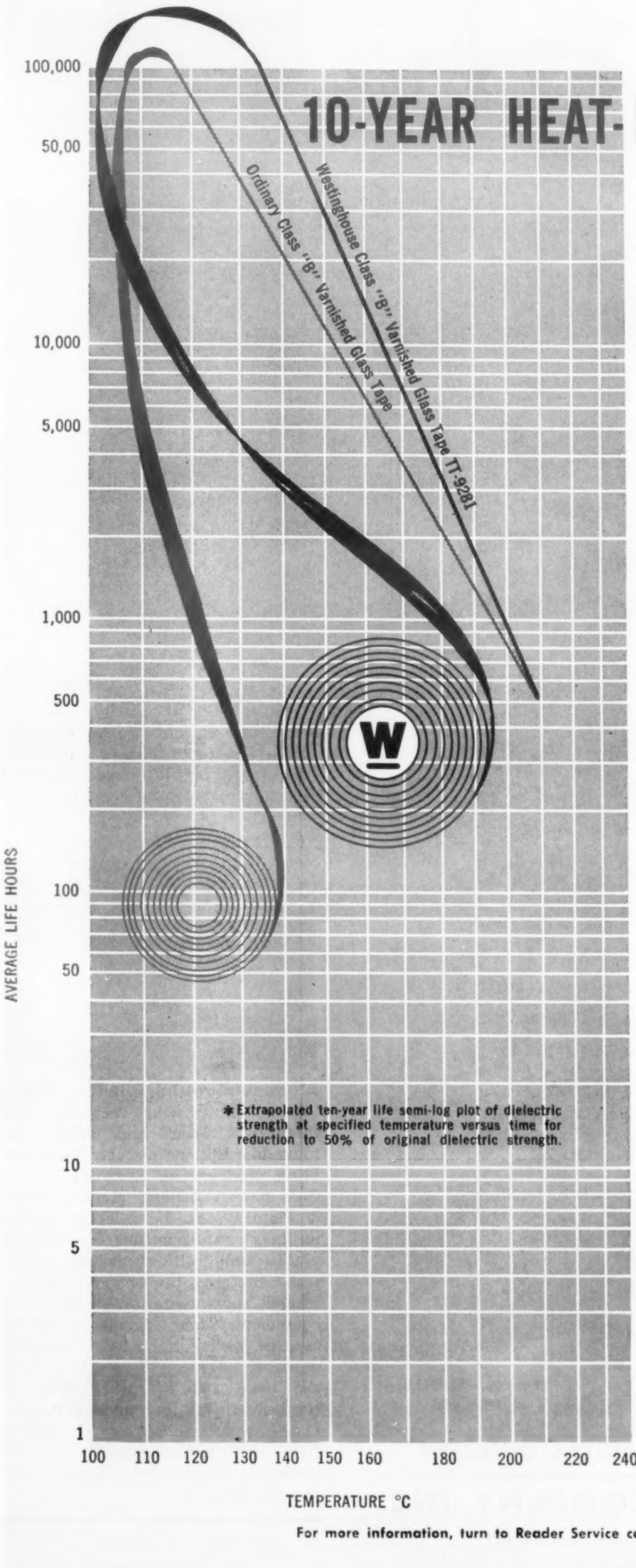
The system is so precise that it can detect and maintain the level of the titanium ingot to within 0.01 in. of its ideal operating position. If for any reason the ingot moves beyond its prescribed limits, the gamma ray control shuts down the furnace.

Although designed expressly for the titanium furnace, the gamma ray control could be used on other types of furnaces.

Standards for Abrasives Object of New Group

A group of men interested in many different facets of the abrasive field have formed a new nationwide technical and study organization named the American Society for Abrasives.

Function of the society will be to hold meetings for technical dis-



10-YEAR HEAT-RESISTANCE TEST

Shows Westinghouse Varnished Glass Cloth and Glass Tape Is a "True" Class "B" Insulating Material!

What do you demand of a true Class "B" insulating material?

That it provide good heat, abrasion and solvent resistance, plus high dielectric strength at 130°, of course. But for *how long?* Five *minutes?* Five *months?* Five *years?*

*Westinghouse Varnished Glass Cloth and Tape TT-9281 has shown the equivalent of ten years heat resistance at Class "B" temperatures!**

Furthermore, this amazing resistance is achieved without the sacrifice of other properties. The continuous filament glass fabric, coated with quality heat resistant resins, also provides excellent flexibility, oil resistance, tensile strength and handling characteristics.

That's why Westinghouse Varnished Glass Cloth and Tape TT-9281 is called a "true" Class "B" insulating material.

The same quality is built into the *complete* Leadership Line of Westinghouse flexible tapes, organic resins and varnishes for virtually *every* insulating specification. Whatever your insulating problem, why not call your Westinghouse sales engineer today, or send the coupon below for our complete Leadership Line catalog? J-06637

* Extrapolated ten-year life semi-log plot of dielectric strength at specified temperature versus time for reduction to 50% of original dielectric strength.

YOU CAN BE SURE...IF IT'S

Westinghouse

Westinghouse Electric Corporation M&M-7-57
MICARTA Division, Trafford, Pa.

Please send me your *Leadership Line Catalog* on Westinghouse flexible insulation, tapes, resins and varnishes.

NAME________________

TITLE________________

COMPANY________________

ADDRESS________________

CITY________________

STATE________________

For more information, turn to Reader Service card, circle No. 407

cussions on all phases of the use, manufacture, and improvement of abrasives and to exchange knowledge gained from practical experience. The long range objective of the society is the establishment of uniform standards for abrasives and abrasive products.

Chapters have thus far been organized in New England, the Middle Atlantic States and Michigan. Executive officers of the society are: national chairman, T. J. O'Connell, Macklin Co.; president, John Y. Arnold, Carpenter Steel Co.; vice-president, Ray B. Rider, General Electric Co.; secretary, Jan L. Deelman, Attorney; treasurer, Willard Miller, Mt. Penn Trust Co.

There are three classes of membership: Student, Senior and Associate. Further information may be obtained from Jan L. Deelman, American Society for Abrasives, 222 Berks County Trust Bldg., Reading, Pa.

Aluminum rolling plant — Single, tapered plate wing sections, with integral stiffeners and milled contours like the one pictured here, are being produced at Reynolds Metals Co.'s newest facility, McCook Sheet & Plate Works. In order to handle military requirements for thicker plates and multidimensional sculptured surfaces, the company has installed several improved types of equipment. These include: a 145-in. tapered rolling mill; twin fixed-bed gantry-type skin millers with a work bed over 100 ft. long; what is claimed to be the world's largest plate stretcher, having a pulling force of 16 million pounds; and the industry's first horizontal-plate heat treating furnace.

For more information, turn to Reader Service card, circle No. 502

News OF INDUSTRY

Engineers

Konrad W. Frederiksen, former assistant director of engineering and chief design engineer, Chas. Pfizer & Co., Inc., has retired. He is succeeded by **George W. Rocklein, Jr. Enno F. Harger** becomes assistant chief design engineer, and **Joseph J. Capo**, senior design engineer.

Harold D. Prior is now technical director of Chas. Taylor's Sons Co., a National Lead Co. subsidiary.

R. K. Annis has been promoted to the post of development engineer, Fairbanks, Morse & Co.

George Burnham IV has been appointed assistant vice-president-Philadelphia, United States Steel Corp.

Arthur C. Ellsworth, Jr. is now special projects engineer for Columbia-Southern Chemical Corp.

E. A. Corns, formerly director of research, Lee Wilson Engineering Co., Inc., is administrative assistant for Lee Wilson Proprietorship Operations. He is succeeded by **C. C. Blackman. R. R. Hill** succeeds Blackman as assistant chief engineer; **J. R. Moran** takes over the duties of assistant superintendent of Service and Construction; and **E. P. Usiak** becomes combustion engineer.

Julian Silverberg has been promoted to senior welding engineer, Maytag Co.

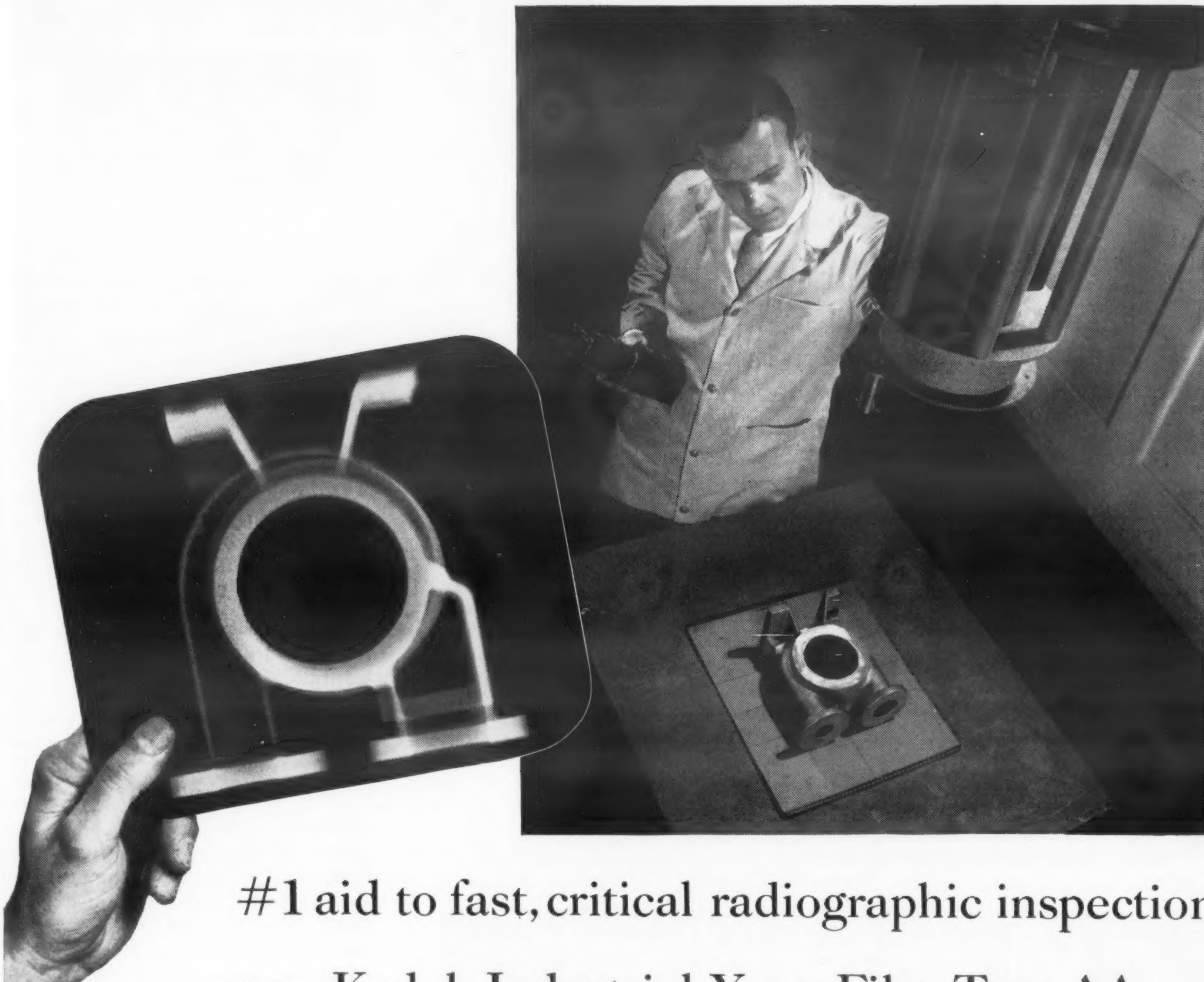
R. A. Burritt has been appointed vice-president and factory manager, J. J. Tourek Mfg. Co.

Andrew H. Bergeson is now vice-president in charge of Stromberg-Carlson's Washington office.

Dr. Alio J. Buselli has been appointed manager of chemical research, W. R. Grace & Co.'s Polymer Chemicals Div.

National Assn. of Corrosion Engineers presented a certificate and honorarium to Thor N. Rhodin, Du Pont engineer, for "the best paper published during the year by an author under 35 years of age."

(continued on p 216)



News OF INDUSTRY

Leonid A. Umansky, retired manager of Systems Application Engineering, General Electric Co., died at his home recently. Mr. Umansky was last year's recipient of the Thomas A. Edison Medal for "his outstanding contributions to the electrification of industry."

O. B. J. Fraser, assistant manager, International Nickel Co.'s Development and Research Div., has been awarded honorary membership in the American Welding Society.

Edward E. Slowter has been elected vice president of Battelle Memorial Institute.

Dr. F. Meade Bailey has been named manager of advanced engineering for the General Electric Industry Control Dept., Roanoke, Va.

Edward C. Wagner has been appointed to the new post of assistant to the vice president for engineering, Ford Instrument Co., Div. of Sperry Rand Corp. **Michael A. Moscarello** has been appointed engineering director for marine equipment.

George F. Copeland is now division industrial engineer in charge of the Bearing Div., Industrial Engineering, Timken Roller Bearing Co.

Dr. Albert Muller's new assignment at Air Reduction Co., Inc. is assistant to the president, Air Reduction Sales Co. He will assist in the acquisition and development of new products and processes.

Richard Ochs is now production manager, Instruments Div., Philips Electronics, Inc.

Companies

McGraw-Edison Co. has acquired the assets and business of **Griswold Mfg. Co.**

Columbia Steel & Shafting Co. has purchased property at Scottsdale, Pa., for the manufacture of cold drawn stainless steel tubing. The plant will operate as a part of Columbia's Summerill Tubing Div.

Firth Sterling, Inc. announces formation of **Firth Sterling, Ltd.** (Canada). The new company is jointly

For more information, turn to Reader Service card, circle No. 507

For more information, turn to Reader Service card, circle No. 472

News OF INDUSTRY

financed by Firth and Canadian interests.

Impact Extrusion Products, Inc. has acquired the Zinc Extrusion Div. of Sun Tube Corp.

Minnesota Rubber and Gasket Co. has acquired the assets of General Industrial Products Co., Inc. The firm will operate as the **Minnesota Latex Rubber Co.,** a div. of Minnesota Rubber, and will occupy a new plant adjacent to present facilities.

Motch & Merryweather Machinery Co. and **Avey Drilling Machine Co.** have merged. The latter company will be known as the Avey Div. of Motch & Merryweather.

Nuclear Materials & Equipment Corp. is a new company with main office and plant in Apollo, Pa.

Rek-O-Kut Co., Inc. plans to start operations at its new 25,000-sq-ft New York City plant by July.

Radio Corp. of America has changed the name of its RCA Tube Div. to RCA Electron Tube Div.

Julius Blum & Co., Inc. has completed a plant addition that increases its floor space to 60,000 sq ft.

Universal Transistor Products Corp. is the new name of Universal Atomics Corp.

Societies

American Welding Society elected the following 1957-58 officers at its national meeting: president, Clarence P. Sander, Consolidated Western Steel Div., United States Steel Corp.; first vice-president, Gustav O. Hoglund, Aluminum Co. of America; second vice-president, Charles I. MacGuffie, General Electric Co.; treasurer, Harry E. Rockefeller, Linde Air Products Co. Directors-at-large are: James F. Deffenbaugh, Federal Machine & Welder Co.; Alfred E. Pearson, Ingalls Iron Works Co.; Clarence M. Styer, Pacific Car & Foundry Co.; Robert M. Wilson, Jr., Development and Research Div., International Nickel Co.

AWS honored twenty-three indi-

This invaluable reference guide is yours for the asking! A really *big* catalog, handsomely bound—each page is crammed with important technical information on a wide variety of stainless analyses. There is specific information on each analysis, including its physical and mechanical properties, and data on its corrosion and heat resistance. A special section covers Superior's "super alloy" tubing for aircraft, missiles, etc. Pages are devoted to the selection and application of stainless tubing. Separate sections cover soldering, welding, machining, bending, etc. All this and much, much more! Get your copy while our supply lasts!

Superior Tube
The big name in small tubing
NORRISTOWN, PA.

All analyses .010 to 5/8 in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company,
5710 Smithway Street, Los Angeles 22, Calif. • RAymond 3-1331

SUPERIOR TUBE COMPANY
2006 Germantown Ave., Norristown, Pa.

Rush me my free copy of your Catalog Section 21.

Name________________ Title________

Company________________

Address________________

____

For more information, turn to Reader Service card, circle No. 513

News OF INDUSTRY

viduals with five national and 18 regional awards at its Adams national meeting. The five national award winners are: Fred L. Plummer, Hammond Iron Works — Samuel Wylie, Miller Memorial Award; DeWitt C. Smith, Harnischfeger Corp.—certificate and honorarium; O. B. J. Fraser, Development and Research Div., International Nickel Co. — honorary membership in the Society; Jay Bland, Engineering and Research Dept., Standard Oil Co.—1957 Lincoln Gold Medal; A. N. Kugler, Air Reduction Sales Co.—National Meritorious Service Award.

National Screw Machine Products Assn. elected the following officers at the annual meeting: president, Dana B. Jefferson, Jr., Walker Mfg. Co.; vice-president C. J. Baumgart, Screw Machine Engineering, Inc.; treasurer, Leonard R. Schaffer, Mechanical Art Works, Inc.; executive vice-president, Orrin B. Werntz; and secretary, Margaret S. Ballinger. New trustees elected include: Francis P. Trinkhaus, Crellin Machine Co.; Elwood Leonard, H & H Screw Products, Inc.; Charles L. DeMartin, General Screw Products Corp.; and Charles L. Kerr, Kerr-Lakeside Industries, Inc.

American Zinc Institute has elected S. D. Strauss, American Smelting and Refining Co., president. Vice presidents are: J. D. Bradley, Bunker Hill Co.; Clarence Glass, Anaconda Sales Co.; H. L. Young, American Zinc Sales Co. Directors: John D. Bradley, Bunker Hill Co.; R. B. Caples, Anaconda Co.; E. V. Daveler, American Zinc, Lead and Smelting Co.; Clarence Glass, Anaconda Sales Co.; R. L. McCann, New Jersey Zinc Co.; G. W. Potter, Potter-Sims Mines, Inc.; F. A. Wardlaw, Jr., International Smelting and Refining Co.: H. I. Young, American Zinc, Lead and Smelting Co.; Miles M. Zoller, Eagle-Picher Co.; and William J. Welch, National Lead Co.

Malleable Research and Development Foundation has officially opened its offices in Granville, Ohio. It will administer a research and development program to be conducted in laboratories of the member companies, research institutes and universities.

(News of Meetings on p 222)

News OF INDUSTRY

Meetings

SOCIETY OF AUTOMOTIVE ENGINEERS, West Coast meeting. Seattle. Aug 12-14.

WESTERN ELECTRONIC SHOW AND CONVENTION. San Francisco. Aug 20-23.

SOCIETY OF AUTOMOTIVE ENGINEERS, tractor meeting and production forum. Milwaukee. Sept 9-12.

AMERICAN INSTITUTE OF MINING, METALLURGICAL AND PETROLEUM ENGINEERS, Institute of Metals Div. Chicago. Sept. 16-18.

AMERICAN DIE CASTING INSTITUTE, annual meeting. Chicago. Sept 17-20.

METAL POWDER ASSN., fall meeting. Pocono, Pa. Sept 20-21.

STEEL FOUNDERS' SOCIETY OF AMERICA, fall meeting. Hot Springs, Va. Sept 23-24.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, fall meeting. Hartford, Conn. Sept 23-25.

STANDARDS ENGINEERS SOCIETY, sixth annual meeting. New York City. Sept 23-25.

SIXTH ANNUAL INDUSTRIAL ELECTRONICS SYMPOSIUM. Chicago. Sept 24-25.

NATIONAL SCREW MACHINE PRODUCTS ASSN., fall meeting. Colorado Springs. Sept 29-Oct 3.

SOCIETY OF AUTOMOTIVE ENGINEERS, aeronautic meeting, aircraft production forum and aircraft engineering display. Los Angeles. Oct 1-5.

ELECTROCHEMICAL SOCIETY, INC., fall meeting. Buffalo, N. Y. Oct 6-10.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, fall meeting. Chicago. Oct 7-11.

GRAY IRON FOUNDERS' SOCIETY, annual meeting. Chicago. Oct 9-11.

SOCIETY OF THE PLASTICS INDUSTRY, INC., 13th annual New England Section Conference. Portsmouth, N. H. Oct 10-11.

PRESSED METAL INSTITUTE, annual meeting. Castle Harbour, Bermuda. Oct 13-17.

MAGNESIUM ASSN., annual convention. New York City. Oct 17-18.

NATIONAL ASSN. OF CORROSION ENGINEERS, seventh annual western regional conference, San Diego, Calif. Oct 22-24.

Coming to you in September

MATERIALS SELECTOR ISSUE

This fall you will receive the MATERIALS SELECTOR issue for 1957. It will be mailed to you as the 13th issue of MATERIALS IN DESIGN ENGINEERING.

WHAT IT IS: All editorial pages of the MATERIALS SELECTOR will be in data sheet form. It will provide materials-specifying engineers, designers and other technical men with the most complete and best organized annual reference data available. It offers you two major editorial sections:

Data Section
- Comparisons of Materials
- Properties of Materials
  - Irons and Steels
  - Nonferrous Metals
  - Plastics and Rubber
  - Nonmetallics
    (except Plastics and Rubber)
  - Finishes and Coatings
- Forms and Shapes of Materials

Directory Section
- Suppliers of Materials
  (classified by Materials, Forms and Finishes)
- Addresses of Suppliers

YOU ASKED FOR IT! You and your fellow readers continually ask us for information of all sorts about materials selection. In fact, requests for further information resulting from MATERIALS IN DESIGN ENGINEERING's editorial and advertising pages average better than 225,000 per year! Until now, no one has ever attempted to consolidate reference data in a single annual issue and thus make it easier to determine the answers to the problems that confront you when you select and specify engineering materials.

WE'RE EXCITED because our readers are going to get what they want in the MATERIALS SELECTOR. Watch for the MATERIALS SELECTOR. We know you'll find it the most complete, the most useful, year-round reference issue published.

The Editors
Materials in Design Engineering
(Formerly Materials & Methods)

For more information, turn to Reader Service card, circle No. 481

BOOKS & REPORTS

Books

Symposium on Corona. *American Society for Testing Materials, Philadelphia, 1957. ASTM Special Technical Publication 198. Paper, 6 by 9 in., 32 pp. Price $1.25*

No common or standard methods of corona detection or evaluation of corona resistance of electrical insulation are presently available. Recently ASTM Committee D-9 on Electrical Insulating Materials initiated research and standardization methods for corona detection of electrical insulation. One of the accomplishments of this work was a symposium on corona. Included in the symposium as now published are papers on the effects of corona on thermosetting plastics laminates; corona resistance test methods for laminates and molded and cast materials; corona detection and measurement; and test methods for measuring energy in a gas discharge.

Applied Metallurgy for Engineers. *Malcolm S. Burton. McGraw-Hill Book Co., New York, 1956. Cloth, 6¼ by 9½ in., 407 pp. Price $7.50*

Designed as a college textbook on the elementary principles and applications of metallurgy, this book begins with brief discussions of the nature, production and testing of metals, and the nature of alloys and alloying.

Recent advances in metal science such as shell molding, inert-gas-shielded arc welding and vibrationless mid-air forging are discussed with emphasis on principles rather than on manipulative techniques. The book develops the metallurgical principles involved in metalworking and evaluates these manufacturing processes from an engineer's viewpoint. A list of reference books follows each chapter.

Consulting Services: 1957, *Association of Consulting Chemists & Chemical Engineers, Inc., New York. 1957. Paper, 6 by 9 in., 136 pp. Price $1.*

This book outlines officers, staff and activities of consulting services devoted to solving manufacturing and

CYANAMID

PLASTICS NEWSFRONT

SOCKETS TO MATCH YOUR '57 CHRISTMAS TREE

A more colorful Christmas—1957 is in the making today. To match the trend to Christmas trees sprayed in a host of colors, Conart Co., Inc., is now molding light socket husks in a variety of colored BEETLE® Molding Compounds to be strung on matching wire strands. Sturdy, hard BEETLE is an excellent insulator, and its molded-in color resists heat and discoloration, can't chip off. Conart produces enough husks each month to stretch twice from coast to coast.

LAMINAC® SIGNS WARN OF "OPERATION ELECTROCUTION"

These LAMINAC signs point to a great experiment in sea lamprey control being conducted by U.S. Fish and Wildlife Service in the Great Lakes area. To kill these destructive eellike fish, electrically charged lines are stretched across areas where lampreys return from spawning. Passers-by are warned off by signs posted on land and in the water. To make them waterproof, with warnings that can't wash off, Perry Plastics, Inc., makes the signs of glass-reinforced LAMINAC Polyester Resin. Color is molded in, so signs never need painting and will never rot or rust away.

ANGELIQUE'S CYMEL® AEROSOL WINS CSMA AWARD

1956 saw the first successful all-plastic aerosol spray dispenser made of CYMEL Melamine Molding Compound. And it brought the top Chemical Specialties Manufacturing Association, Inc. award in the class of glass and plastic aerosols to Angelique's CYMEL dispenser for Black Satin Spray Cologne. Plastic aerosols are popular with the ladies, too—feel warm and pleasant in the hand, resist breakage and corrosion, eliminate evaporation. Their success points the way to many new packaging possibilities with CYMEL.

1907 50 1957

AMERICAN CYANAMID COMPANY
PLASTICS AND RESINS DIVISION
34M Rockefeller Plaza, New York 20, N. Y.

In Canada: North American Cyanamid Limited, Toronto and Montreal

Offices in: Boston · Charlotte · Chicago · Cincinnati · Cleveland · Dallas · Detroit
Los Angeles · New York · Oakland · Philadelphia · St. Louis · Seattle

CYANAMID Plastics and Resins Division

MATERIALS FOR TOMORROW

For more information, turn to Reader Service card, circle No. 521

BOOKS & REPORTS

research and development problems, including problems involving adhesives, ceramics, die castings, nonferrous metals, plastics, leather, paper, paints and textiles. The book describes consultants qualifications and alphabetically lists names and locations of consulting agencies.

Reports

Welding cast iron WELDING RODS AND COVERED ELECTRODES FOR WELDING CAST IRON. *July '56. 11 pp. Available from American Welding Society, 33 W. 39th St., New York 18, N. Y. Price 40¢ (AWS A5.15)*

Includes specifications for filler metals used for welding gray cast iron, malleable iron and some alloy cast irons. Sixteen classifications of filler metal are covered, including cast iron, copper-base, nickel-base and mild steel electrodes for shielded metal arc welding. Also included are cast iron and copper-base welding rods for oxyacetylene and carbon arc welding.

Porosity graded alloy MECHANICAL PROPERTIES OF POROSITY GRADED 195 ALLOY: PART 1—TENSILE PROPERTIES. *I. J. Feinberg, Naval Ordnance Lab. June '56. 44 pp. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price $1.25 (PB 121546)*

Study of the effects of hydrogen gas porosity on tensile properties of 195 casting alloy. Metallographic illustrations of elongated hydrogen gas porosity in the alloy are compared with derived tensile properties.

Vacuum brazing AN INVESTIGATION OF HIGH TEMPERATURE VACUUM AND HYDROGEN FURNACE BRAZING. *W. E. Russell and J. P. Wisner. Mar '57. 29 pp, illus. Available from National Advisory Committee for Aeronautics, 1512 H St., N.W., Wash. 25, D. C. (TN 3932)*

Describes vacuum and hydrogen brazing of four heat resistant alloys with two types of high temperature brazing alloys. The effect of time at various brazing temperatures on the 1200 F shear strength of joints and on the base metal tensile strength and elongation was studied.

Reinforced plastics THE MECHANICAL PROPERTIES OF POLYESTER LAMINATES REINFORCED WITH HIGH MODULUS GLASS FABRIC. *F. Werren, Forest Products Lab. Sept '56. 22 pp. Available from Office of Technical Serv-*

AMPCO — ONE-SOURCE SERVICE FROM RAW MATERIAL TO FINISHED PRODUCT

Does your sketch suggest a copper-base alloy?...

You name it...

Ampco can supply it, in the form that's best

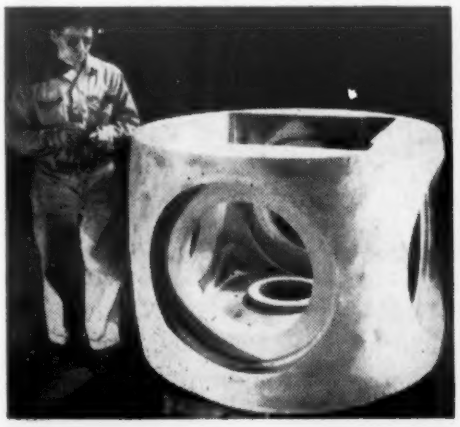
You enjoy design flexibility, with versatile Ampco alloys

Among more than 100 Ampco copper-base alloys is the one you need for

— resistance to wear, impact, fatigue, corrosion
— excellent bearing qualities
— retention of physical characteristics at temperatures from 600°F down to -400°F.

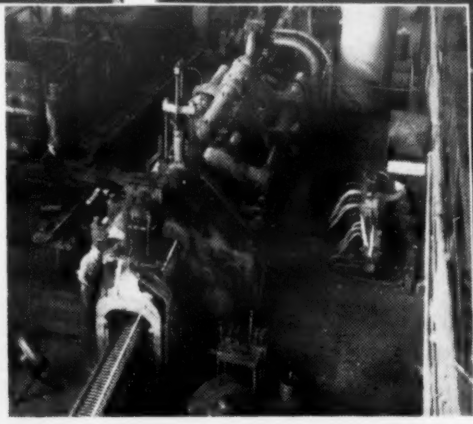
And equally important, you can select the best, most economical form of production — sand casting, centrifugal casting, shell mold, precision casting, forging, fabrication, extrusion, sheet, plate.

Call in your Ampco field engineer.
Write for Bulletin 33.



Sand castings in any size up to 14,000 pounds — and *centrifugal castings* up to five tons—are produced in Ampco foundries.

Ampco's one-source service includes production-run machining of copper-base alloys to quality standards of the aircraft industry.

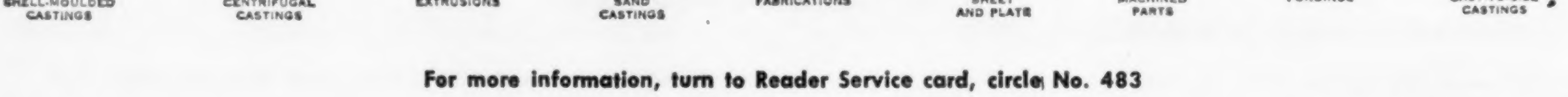


2,275-ton hydraulic press in Ampco's modern, laboratory-controlled mill for extruding rods, bars, hollow rounds, and shapes.

D-60

THE METAL WITHOUT AN EQUAL

AMPCO METAL, INC. Dept. MA-7, Milwaukee 46, Wisconsin • West Coast Plant: Burbank, California



For more information, turn to Reader Service card, circle No. 483

BOOKS & REPORTS

ices, Dept. of Commerce, Wash. 25, D. C. Price 75¢ (PB 121683)

Strength and elastic properties of a typical polyester laminate reinforced with 181 glass fabric are shown to be equal to or higher than properties of polyester laminates reinforced with H.M. 18 (high modulus) glass fabric. Tensile, compression and flexure test values are given for each laminate.

Soldering of aluminum ULTRASONIC SOLDERING OF ALUMINUM. *J. B. Jones and J. G. Thomas, Aeroprojects, Inc. Feb '55. 68 pp. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price $1.75 (PB 121551)*

Successful application of ultrasonic soldering techniques to aluminum is demonstrated in this report. Ultrasonic techniques proved effective in fluxless tinning with all of the solder alloys. The report gives details of ultrasonic exposure time and soldering temperature relationships. Also studied are the effects of joint configuration and filler metal thickness on joint strength.

Finishes for nylon RESEARCH AND DEVELOPMENT OF ABRASION RESISTANT TREATMENTS FOR NYLON WEBBINGS. *G. Thomson, J. S. Panto, M. J. Coplan and E. R Kaswell, Fabric Research Laboratories, Inc. June '56. 79 pp, illus. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price $2 (PB 121494)*

Evaluates commercially available water dispersions of different types of resins such as acrylic, acrylonitrile, natural rubber and silicone as finishes for nylon webbings. Webbings treated with one particular silicone emulsion were superior to all other treated samples in abrasion resistance, low temperature flexibility and resistance to heat aging.

Steel outlook COMMERCIAL OUTLOOK FOR STEEL—1957-1960. *100 pp. Available from Herman B. Director Associates, 1511 K St., Wash. 5, D. C. Price $10*

This report reviews the entire steel situation for the four-year period, 1957 through 1960. It is supported by over 50 statistical tables and

New!
SPECIAL PURPOSE LOOM SPECIAL ROLLS REQUIRED

New 380" dryer felt loom manufactured by Southeastern Loom and Machine Works, a Division of Abney Mills. Manufacturers of special machinery for the textile and paper industries, Southeastern recently completed installation of four heavy-duty looms of a type formerly successfully manufactured only in England.

ACIPCO

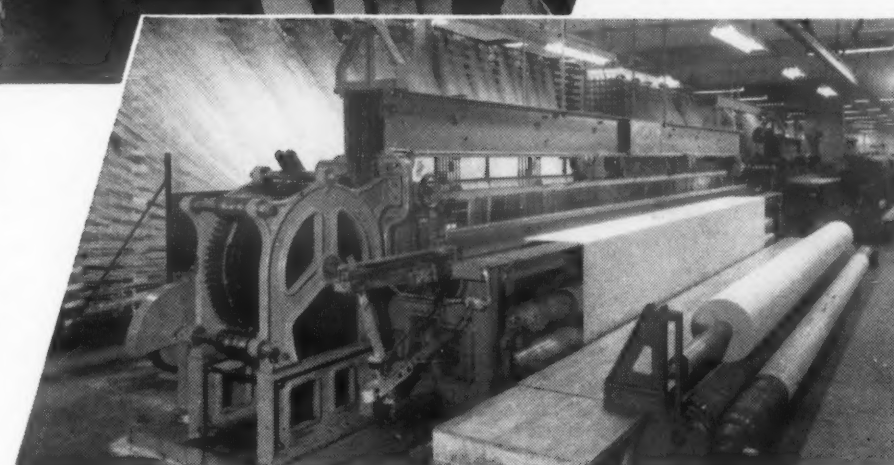
Centrifugally Spun STEEL TUBES

Rolls in this 380" Southeastern loom, designed for weaving thick dryer felts for the paper industry, must stand extremely heavy loading. Minimum roll deflection and run-out are vital to successful operation.

The long length necessary—33′6″—imposed a requirement for unusual dynamic balance and dimensional stability in these rolls.

Southeastern Loom and Machine Works, a Division of Abney Mills, selected ACIPCO centrifugally spun steel tubes for the let-off and take-up rolls in this new loom. Because ACIPCO's centrifugal process produces tubes with *inherent* dynamic balance and dimensional stability, and because they can be produced in the longer lengths now being specified by modern equipment manufacturers, the selection was right from the start.

When function and design set up unusual or difficult requirements for the tubular steel or alloy iron parts in your application, call on ACIPCO. You'll get a combination of expert technical assistance, manufacturing competence and high quality centrifugally spun tubing that produces successful results.



Let-off and take-up rolls in this Southeastern dryer felt loom were fabricated from ACIPCO centrifugally spun tubing. Large rolls are 33′6″ long, with 10½″ OD and 2½″ wall thickness.

VERSATILE ACIPCO CENTRIFUGALLY SPUN STEEL TUBES

are used in the manufacture of calender, engraving, press, slitter, rewinder, plate cylinder, squeeze and starch bath rolls, as well as in hundreds of other industrial applications.

SIZE RANGE: Lengths up to 410″ to meet modern machinery requirements have been produced. OD's from 2.25″ to 50″; wall thicknesses from .25″ to 4″.

ANALYSES: All alloy grades in steel and cast iron, including heat and corrosion resistant stainless steel; plain carbon grades and special non-standard analyses.

AMERICAN CAST IRON PIPE CO.
Special Products Division
BIRMINGHAM 2, ALABAMA

DISTRIBUTORS

Austin-Hastings Co., Inc.
226 Binney Street
Cambridge 42, Mass.

Peter A. Frasse and Co., Inc.
17 Grand Street
New York 13, New York

Lyman Tube & Bearings, Ltd.
920 Ste. Sophie Lane
Montreal 3, Canada

Vinson Steel & Aluminum Co.
4606 Singleton Blvd.
Dallas 7, Texas

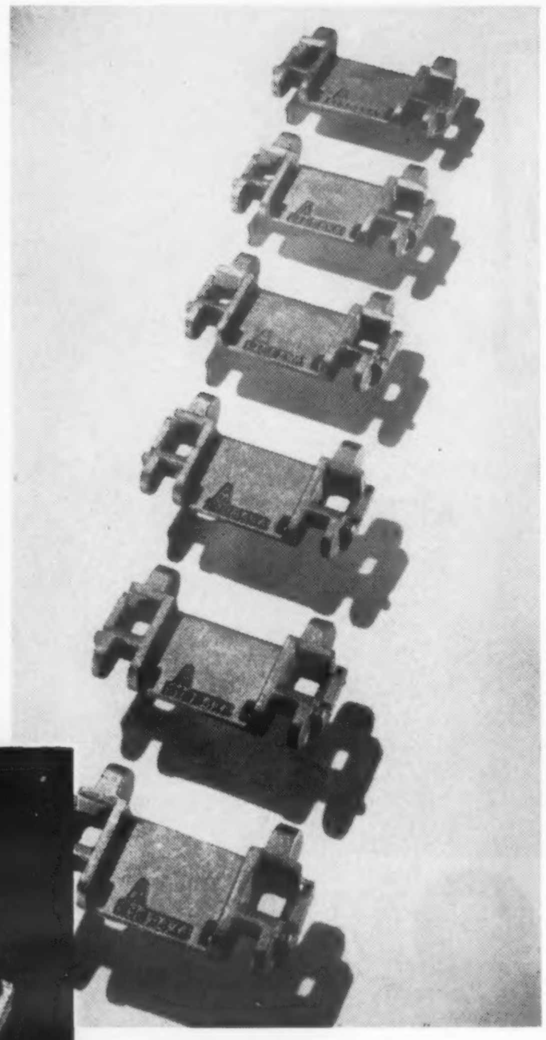
J. M. Tull Metal & Supply Co.
285 Marietta St., N.W
Atlanta, Georgia

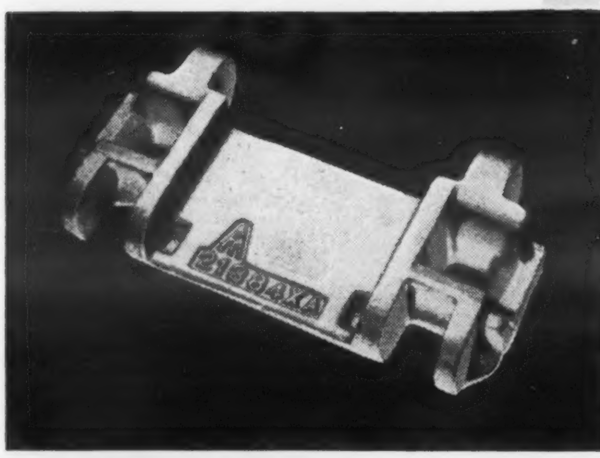
C. A. Roberts Company
2401 Twenty-fifth Avenue
Franklin Park, Ill.

Strong, Carlisle & Hammond Co.
1392 W. Third Street
Cleveland 13, Ohio

Ducommun Metals & Supply Co.
4890 So. Alameda St.
Los Angeles 54, California

For more information, turn to Reader Service card, circle No. 494





BOOKS & REPORTS

charts showing the supply-demand picture for steel during this period. According to the report, the steel industry will bring into production 146 million tons of ingot capacity by 1960 with emphasis on steel structural shapes, plates and tubular goods. The report contains a simple method for estimating steel demand for various levels of economic activity.

Aluminum alloy MECHANICAL PROPERTY, CORROSION AND WELDING STUDIES ON 6066 ALUMINUM ALLOY. *J. D. Wood, Wright Air Development Center. June '56. 36 pp. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price $1 (PB 121497)*

An evaluation of aluminum alloy 6066, an aluminum-magnesium-silicon-copper-manganese-chromium alloy. Rolled sheets of the alloy have strength properties almost equal to strength properties of extrusions. Stress corrosion life exceeds 2900 hr, although elongation decreases to about 2% after exposure. The alloy should be protected against severe corrosive media by cladding, anodizing or painting.

Steel casting techniques STEEL CASTING TECHNIQUES. *Massachusetts Institute of Technology. Feb '54. 40 pp. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price $1 (PB 111914)*
Discusses hot tearing of steel castings in terms of tearing temperatures and stresses. Tearing stresses of plain carbon steels of various compositions were measured from 1700 to 2500 F. Describes how deoxidation practice, and manganese, silicon, carbon, sulfur and phosphorous contents affect the properties of steel castings. Metallographic examinations were made of different types of hot tears and nonmetallic inclusions.

Stainless steel cracking FURTHER STUDIES ON STAINLESS STEEL HOT CRACKING. *P. P. Puzak and H. Rischall, Naval Research Lab. Nov '56. 12 pp. Available from Office of Technical Services, Dept. of Commerce, Wash. 25, D. C. Price 50¢ (PB 121569)*

Results of this study support a hypothesis drawn from earlier studies that grain boundary liquation is responsible for base metal hot cracking. Additional findings for a type 347 stainless steel were compared with the properties of a standard 304 stainless steel.

advertising sales staff

Materials in Design Engineering • 430 Park Ave., New York 22, N.Y. • MUrray Hill 8-8600

M. RANDOLPH LONG • *Advertising Sales Manager*

NEW YORK:
A. STEWART HALE — *District Manager*
GEORGE A. FOX, JR. — *District Manager*
BEVIN SMITH — *District Manager*

CHICAGO: 111 W. Washington St., RAndolph 6-8497
A. E. FOUNTAIN — *District Manager*
PHILIP O'KEEFE — *District Manager*

CLEVELAND: 815 Superior Ave. N.E., PRospect 1-5583
H. CHARLES ESGAR — *District Manager*
D. W. HUETTNER — *District Manager*

SAN FRANCISCO: 625 Market St. YUkon 6-0647
ROY M. McDONALD — *District Manager*

LOS ANGELES: 3727 West 6th St., DUnkirk 7-5391
C. J. CRABB, JR. — *District Manager*

SEATTLE: 1008 Western Ave., ELliott 3766
HARRY ABNEY — *District Manager*

TULSA: 2010 South Utica, RIverside 3-1981
TED R. TRAUTMANN — *District Manager*

HOUSTON: 3217 Montrose Blvd., JAckson 9-6711
FRANK N. VICKREY — *District Manager*

DENVER: Colorado Nat'l Bank Bldg., KEystone 4-4669
ROBERT H. HEIDERSBACH — *District Manager*

THE LAST WORD

by ***H. R. Clauser,*** *Editor*

Coming—Another Awards Competition

Below is the plaque presented to F. L. Talcott of Westinghouse Electric Corp. at the dinner in New York City honoring the winners in our 1957 Awards Competition for Best Use of Materials in Product Design. As first award winner he also received a check for $500. Most of the other 15 award winners also attended personally to receive their prizes.

We were pleased to hear many favorable comments about the awards program at this affair as well as at our Design Engineering Show booth where the winning entries were displayed. Plans are now being made for this year's competition, so it isn't too early to start thinking about your entries. Details will be published in our September issue.

How Much 'General Interest'?

Should an engineering magazine run nontechnical articles of general interest on such subjects as "how to read technical magazines faster," or "how to remember facts and figures"? We have been asking ourselves this question for a long time. My personal feeling has been that, as an engineering magazine, we should stick pretty closely to our technical coverage and let the general circulation magazines use their space on articles of this type. But some of my colleagues disagree, and the trend in business papers seems to be opposite to my view on the matter. For example, an engineering magazine recently had an article on how an engineer should dress. How do you, the reader, feel?

Drop us a post card or a letter and give us your opinions or suggestions. If the response indicates a wide enough desire for general interest articles we could be persuaded to do something about it.

A Dissent, An Answer

My Last Word item in May mildly protesting the $125 fee charged to attend the titanium symposium, sponsored by the Metals Engineering Institute of the American Society for Metals and held during the Western Metal Congress, ruffled a little fur here and there. One correspondent drew our attention to similar symposiums held at New York University with about the same fee, and suggested that we therefore also criticize NYU. This comment misses the main point I tried to make. My principal objection was to "holding special symposia for which there is a high admission charge during an otherwise *open* and *free* convention." If and when any university sponsors activities at technical society meetings for which they charge any such fee I will certainly enter my protest.

A Bouquet

One of the youngest of the many trade associations concerned with materials and forms is the Investment Casting Institute. Since its inception in 1953 it has done, in four years, what has taken a considerably longer time for many other trade associations to accomplish. At its recent annual meeting it issued an engineering and design manual providing detailed information for present and potential users of investment castings (see p 207). Even before this, the association produced a number of data sheets which have now been incorporated in the manual.

This is an example of trade associations at their best, and it illustrates what an industry can do when it unites to help its customers in order to help itself.